WORLD PETROLEUM

FEBRUARY, 1942

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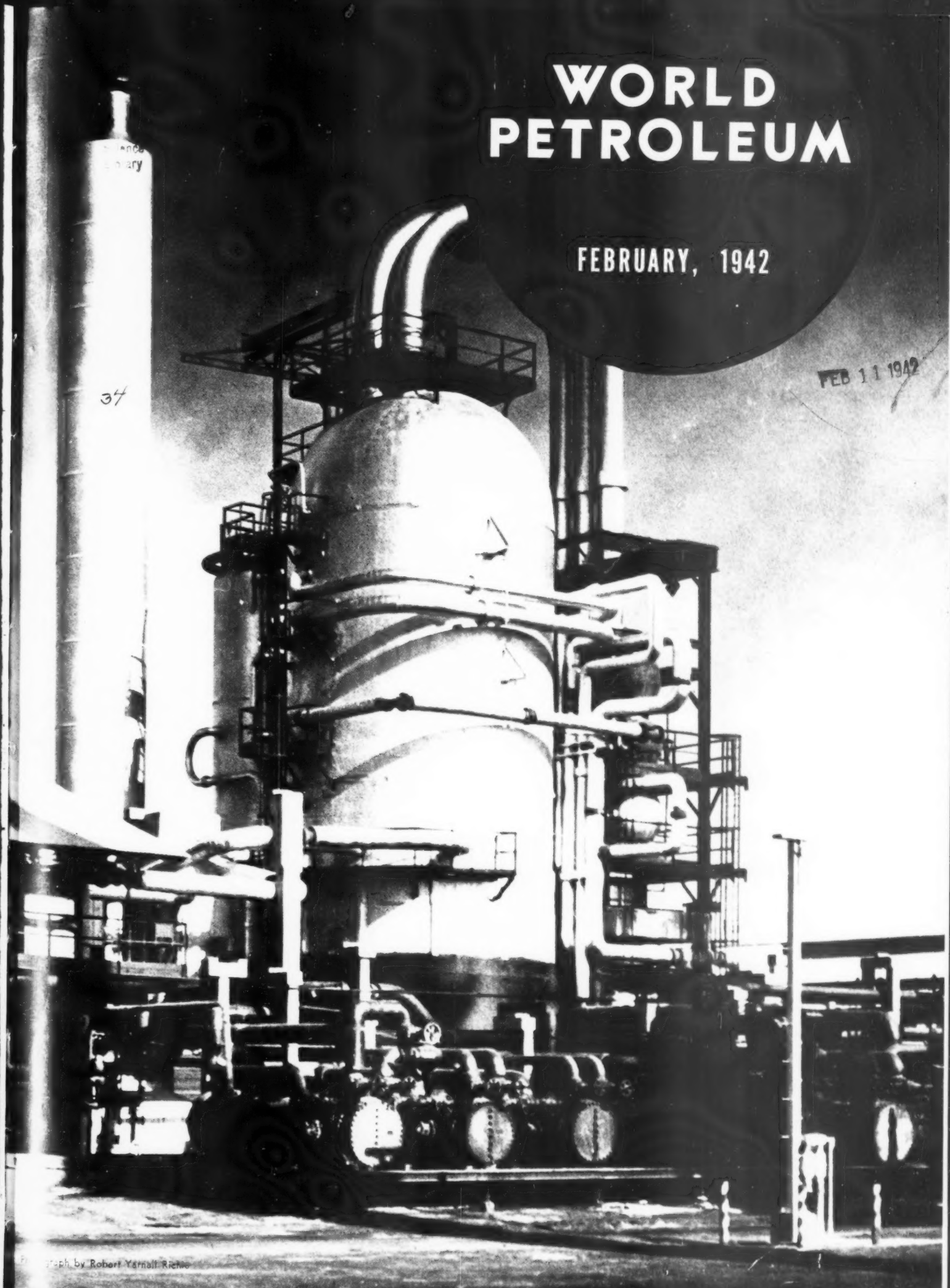

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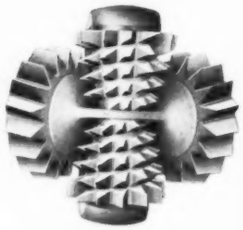

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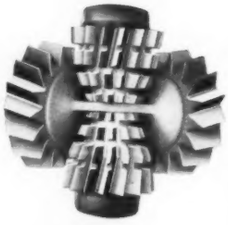

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WORLD PETROLEUM

Incorporating Petroleum Equipment Exporter

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One of thousands of medium pumping wells in Texas, backbone of U. S. 1,405,830,000 bbl. production in 1941. Photo by Ulric Meisel.

EDITORIAL

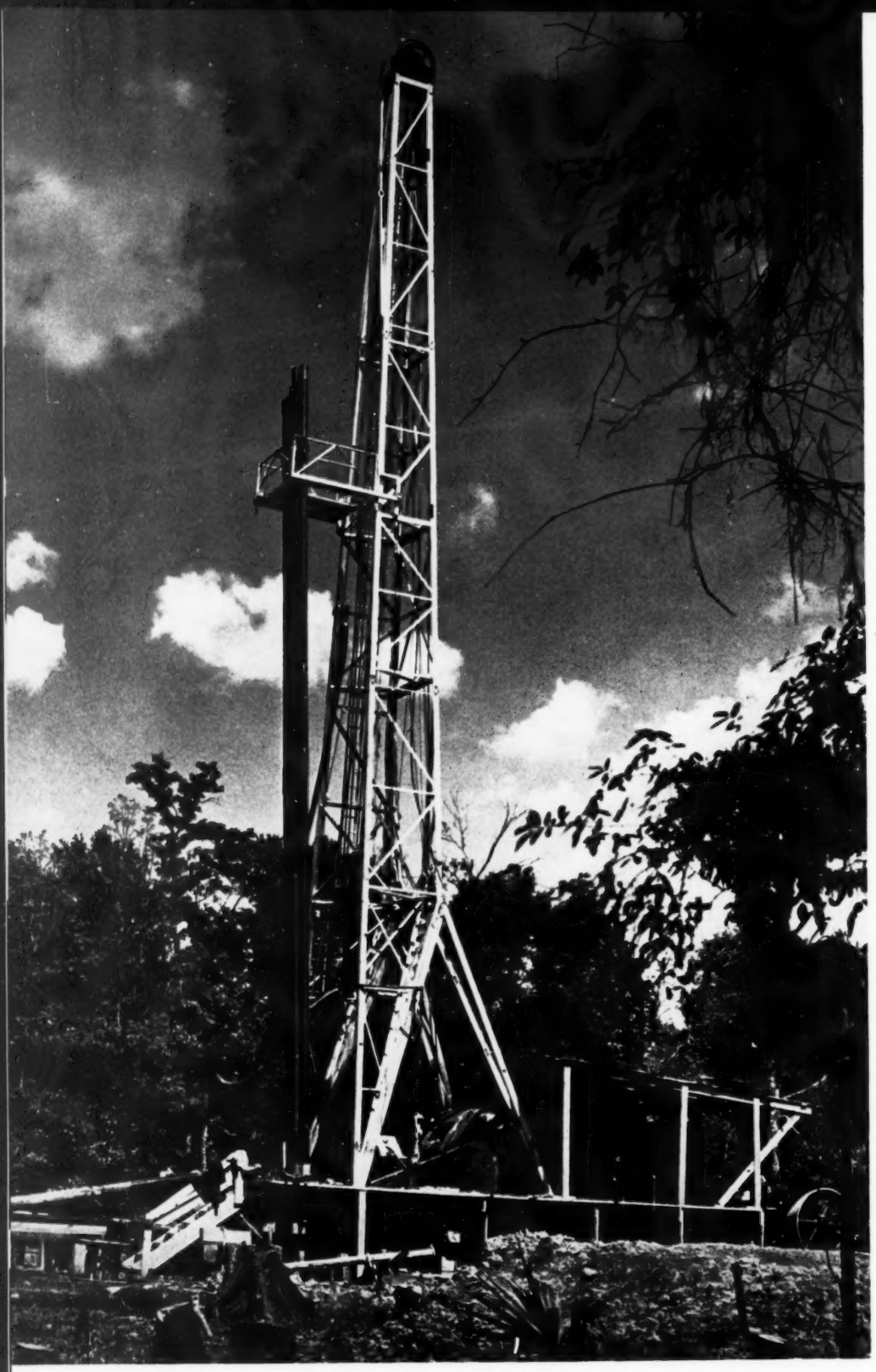
INDUSTRIAL EFFORT AND THE WAR PROGRAM

IN A WAR such as that in which the United States is involved the greatest single problem is that of proper correlation of effort. The problem is complicatd by the fact that by force of circumstances this country must produce the fighting tools and a vast amount of accessory material not only for arming, equipping and supplying its own rapidly growing forces but also to provide a great part of the requirements of the other members of the United Nations. Under this condition it is simply impossible to fill all the ordinary needs of the civilian populace, even some that customarily are considered indispensable. This fact is being impressed upon the public by the restrictions and rationing that are beginning to be put into effect and that will become more extensive as time goes on. More than that, it is impossible to satisfy at once all the pressing demands for actual war materials coming from all the different fighting fronts. Some deficiencies are inevitable.

This point is worth reiteration because it has a direct and important bearing upon the course that all branches of industry, including the oil industry, must follow from this time forward. While the oil industry is being asked to increase production, extend exploration and intensify wildcat drilling, it is expected to do this with fewer tools and less labor than have been available in the past. The forty acre rule applied to drilling may operate in many places to hamper rather than to expedite desired results, but it represents an attempt to reconcile an acknowledged need with an unavoidable restriction. The problem of transportation, made suddenly more acute by the transfer of many tankers from the Atlantic to the Pacific and by sinkings in both oceans, is complicated by the possibility that steel for the building of pipe lines cannot be spared from the construction of ships or tanks or anti-aircraft guns. Another case in point is the debate over the decision to effectuate a huge increase in the production of synthetic rubber which is superimposed upon plans for a vast expansion in the output of aviation fuel. Both depend upon petroleum for their basic material and differences of opinion have been expressed as to whether the latter part of the program can be carried out without interference with the former. Actually the issue is not so much the ability of the petroleum industry to supply the basic materials as one of finding the structural equipment for an increasing number of large sized plants. The practicable must balance the desirable.

In the attempt to adjust the oil industry to its proper place in a many-sided war effort, mistakes are bound to occur. They can and doubtless will be corrected, but aside from these the industry must operate under handicaps due to irreducible demands from other quarters. One means of alleviating the difficulties is by careful attention to the proper maintenance of exsting mechanical equipment and to its most effective use. A manufacturer whose principal customers are oil companies recently expressed the opinion that in actual practice heretofore followed oil field equipment often was utilized to no more than fifty percent of its potential capacity. His suggestion is that manufacturers and operators unite in a campaign to promote the use of equipment to the fullest practicable extent and to insist upon its careful maintenance as a means of prolonging its useful life. Other economies may be worked out.

Under the organization set up by the oil industry and with the cooperation extended by the personnel of the Office of Petroleum Coordinator, full consideration for the industry's essential needs is assured. In spite of all that can be done, however, the industry is bound to be subjected, so long as the war emergency continues, to restrictions that will be irksome and may even prevent the attainment of the full effectiveness otherwise possible, but that must be accepted in recognition of the fact that oil is only a part, though a highly important part, of a coordinated war machine.



OIL'S ROLE IN A WAR OF MACHINES

By Robert E. Allen

Director of the Production Division
Office of the Petroleum Coordinator

TOTAL WAR which now engulfs the United States means for the petroleum industry the undertaking of an assignment the like of which it has never faced before.

That assignment, simply stated, is this:

To produce every last drop of oil of the types required by our fighting forces and vital defense industries, and to do so with the least waste of petroleum resources and with a minimum expenditure of the critical materials essential to the war effort.

The job is tremendous. By the cruel nature of things this is a war of machines. Mechanized warfare demands oil and more oil for planes, battleships, tanks, wherever they may be and at the time needed. With the final outcome of the conflict with the Axis pirates depending very largely on American ability to fill this need 100 percent, how then can the production branch of the petroleum industry best be organized for the task ahead?

As the Petroleum Coordinator for National Defense has said so ably, "The national emergency no longer permits the present haphazard participation in supplying the national demand for petroleum that has heretofore characterized the production of many of the oil producing states and of many fields."

For the 180,000 operators engaged in production of petroleum, this means that from now on out they must devote themselves unstintingly to the task of so conducting their operations as to assure the maximum economic recovery of oil for the victory effort. There must be waste neither of this vital natural resource nor of the materials necessary to its discovery, development and production.

Depletion of known reserves must be offset by new discoveries. Wildcatting must go forward unceasingly. There must be maintained—constantly—a backlog, a surplus, of underground reserves consistent with current and future demands. Only by so doing, can we dare hope for long to hold productive capacity at required levels.

At the same time, development and production must continue apace. Development operations should, and must, be carried on in accordance with recognized engineering practices. There can be no drilling of unnecessary wells; the essential materials are too few, too precious, now that we are at war, to permit of anything like that.

So also with the actual operation of production. Practices detrimental to the efficient operation of individual fields, and conducive to waste of materials, must be abandoned. A stop must be put to excessive, disproportionate withdrawals in relation to known reserves.

Drilling is being carefully regulated by order M-68 and subsequent modifying orders to assure maximum production with the greatest possible economy of steel and other materials vital to the war effort. On this and the facing page is contrasted the light portable rig suitable for exploration drilling and the heavy rig capable of fast deep drilling. Both photographs were taken by Ulric Meisel.

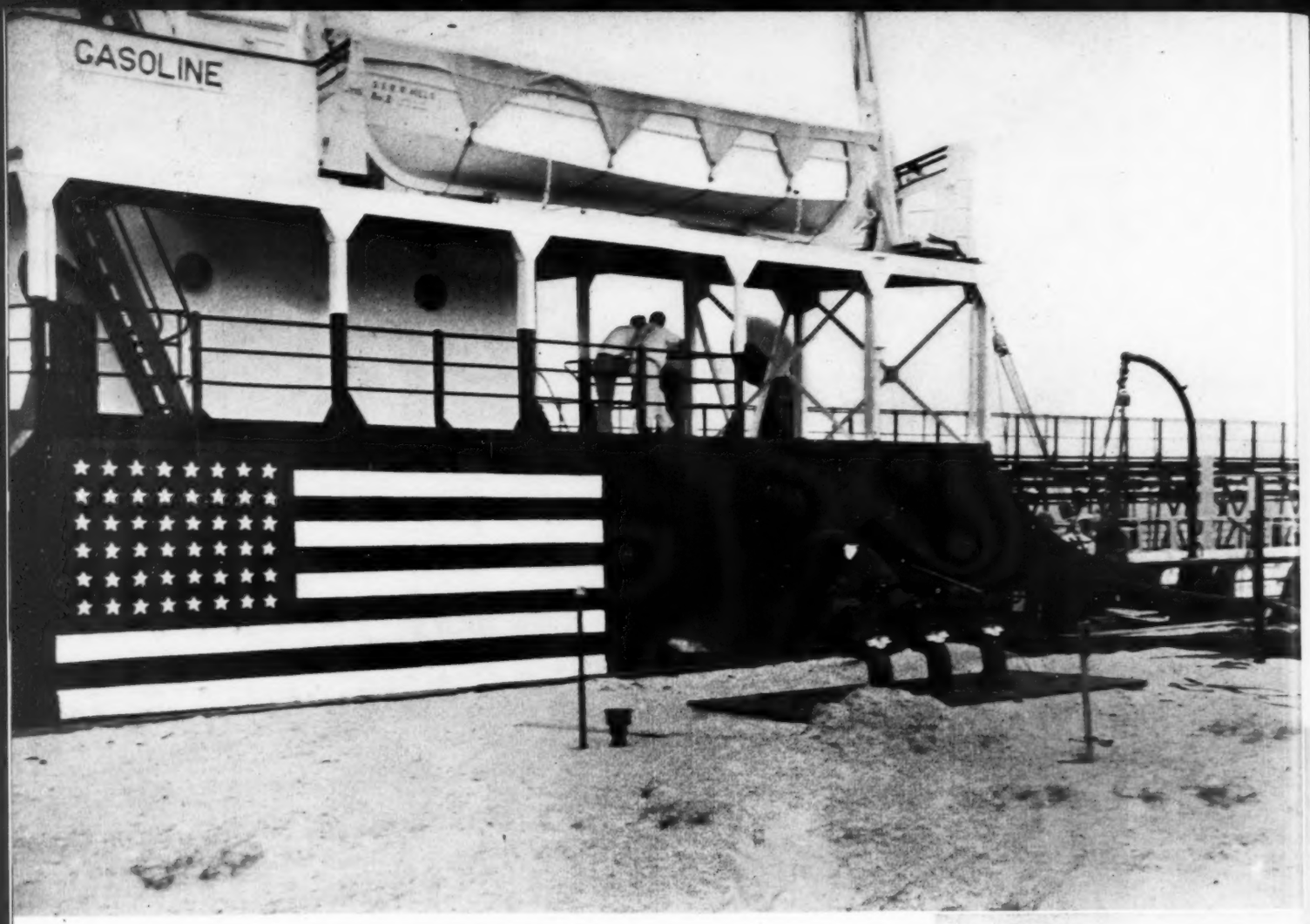
In meeting its assignment, the production branch of the petroleum industry may be assured of constant, sympathetic assistance from the Office of the Petroleum Coordinator. Already much has been accomplished by government aid in the achievement of the ultimate objective.

Conservation Order M-68 is an outstanding example of the effort being made to reconcile the need for continued discovery and proper development of new reserves of petroleum with the greatly reduced quantities of critical materials that will be available for such operations. This order assures, in the first place, the ready availability of materials for the discovery of new reserves. Secondly, it provides for a steady flow of equipment for the drilling or completion of wells drilled in conformity with a uniform spacing pattern of not more than one well to each 40 surface acres in the case of oil wells and 640 acres for gas wells. And, lastly, it provides for the equitable distribution of scarce materials and equipment among existing property and equity interests engaged in the production of petroleum.

Preference Rating Order No. P-98 still further enhances the industry position. Under that order, general ratings will be issued covering all repair and maintenance needs as well as requirements for necessary new development and construction carried on under the terms of Conservation Order M-68.

I desire to point, also, to the action of the Coordinator in initiating the practice of recommending production rates for each oil-producing state. Properly followed, it will foster both conservation and the sustained efficient operation of all oil fields. Production disparities as between states will be modified, assuring a more balanced, efficient program for the national demand for petroleum.

Acceptance of these actions in the spirit that they are intended and in the manner already demonstrated by many members of the industry, cannot help but insure that the end of the war will find a full public recognition of the fact that the production branch of the petroleum industry has played an important part in gaining victory and has contributed to it in a large measure.



MILITARY NEEDS

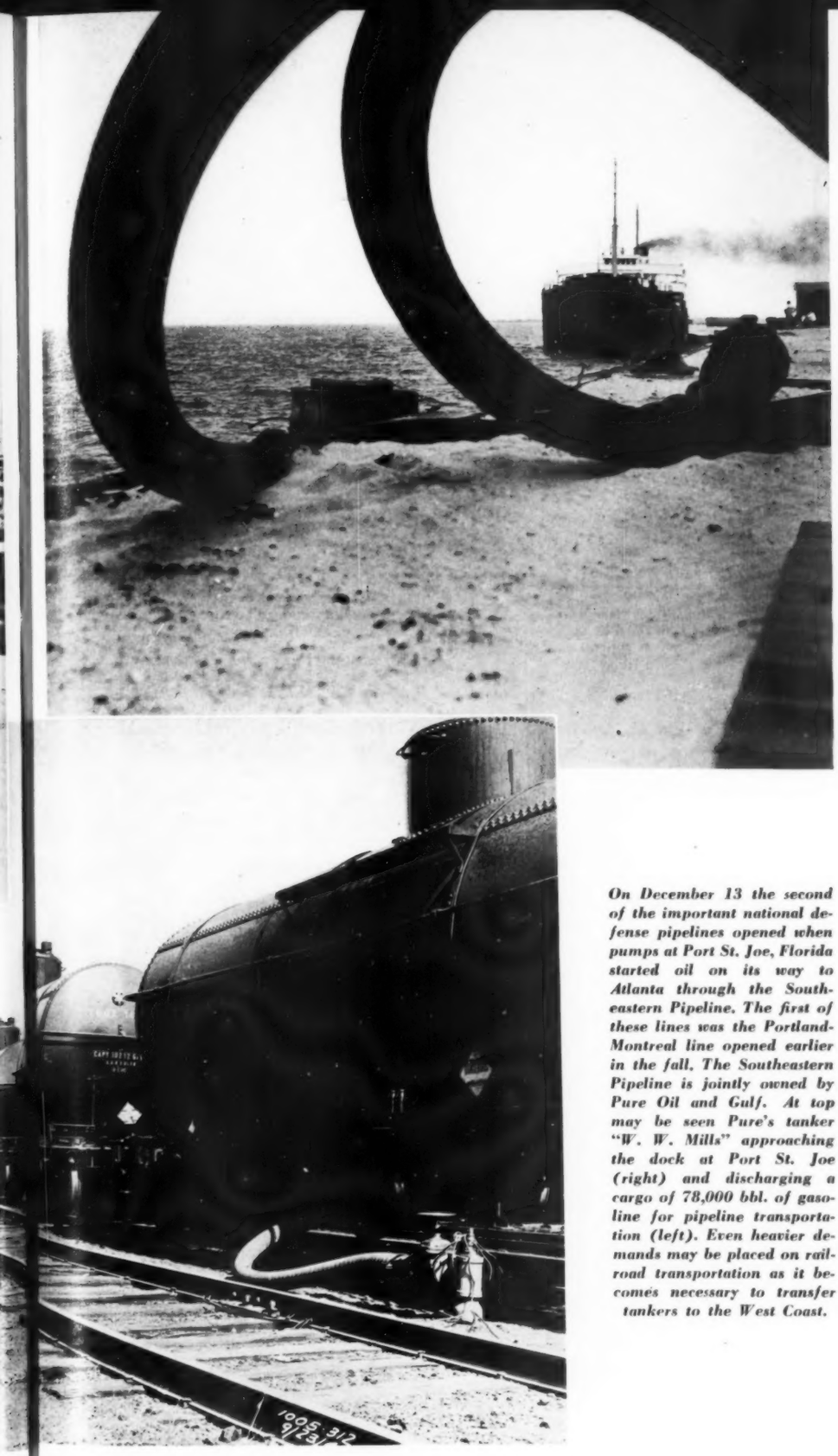
May Raise New Transport Problem

TRANSPORTATION problems of the American oil industry were thought to have been ended late in 1941 with the return to the United States of a number of tankers that had been assigned several months before to the movement of petroleum products to Britain. As a result of the country's involvement in a shooting war the problem has returned in a new and acute form. It is difficult to foretell what proportions it may attain as the war goes on but authorities in Washington who are concerned with the movement of essential commodities, both inside the country and beyond its borders, are basing their calculations on certain eventualities which they regard as well within the range of probability.

Japanese aggression and the plan of campaign that it unfolded set the scene for a war of ships and planes with most of its action in the Western Pacific. Such a conflict requires great quantities of aviation and other gasoline and of fuel oil for ships. Of necessity it required the immediate transfer of tankers to the western ocean and some forty ships were added to this service during the first six weeks of hostilities. Since all supply vessels in any part of the Pacific must be convoyed and since convoying cuts normal speed by one-third to one-half the number of vessels required to perform a given amount of service is increased by fifty to one hundred percent. With the possibility of complete elimination of Netherlands India as a source of petroleum supply, with the great distances to be covered, and with the strong probability of some shipping losses all indications point to a steady and substantial rise in tanker requirements in this field of conflict.

While the war in the Pacific moves to a rising tempo there is definite anticipation that the Battle of the Atlantic may enter a more active phase with the approach of spring and may make further demands upon existing tanker tonnage. The

fueling of American bases, satisfaction of the minimum needs of Latin America and the maintenance of coastwise service along the Pacific littoral, now more essential than before the war, make it inevitable that rising military demands can be met only by withdrawals from the Gulf Coast-Atlantic tanker fleet. These diversions



On December 13 the second of the important national defense pipelines opened when pumps at Port St. Joe, Florida started oil on its way to Atlanta through the Southeastern Pipeline. The first of these lines was the Portland-Montreal line opened earlier in the fall. The Southeastern Pipeline is jointly owned by Pure Oil and Gulf. At top may be seen Pure's tanker "W. W. Mills" approaching the dock at Port St. Joe (right) and discharging a cargo of 78,000 bbl. of gasoline for pipeline transportation (left). Even heavier demands may be placed on railroad transportation as it becomes necessary to transfer tankers to the West Coast.

have begun to make themselves felt but they are likely to continue and to attain much larger proportions than those which raised the spectre of possible east coast shortage late in 1941.

Relief through pipeline construction, so hotly debated last year, no longer figures to the same extent in the picture. Demands upon the steel capacity of the country for purely military requirements have put the building of long distance pipe lines out of the question even where they are most urgently needed. The Southeastern pipe line, from Port St. Joe, Florida, to Atlanta and Chattanooga, was formally opened in December and the Plantation line, from Baton Rouge to Greensboro, North Carolina, will go into service this month. These two lines will be of great assistance in moving products to South Atlantic states where many army camps are located, but they do not reach the important industrial areas of the northern Atlantic seaboard. With the present absorption of sheet steel and tube manufacturing facilities by army and navy orders, pipe line construction for the immediate future will be restricted to routes for which materials have already have been provided or to some few short lines to serve as gathering lines in the fields or to supply connections to refineries. The tentative allocation of 1,843,000 tons of steel for expansion of transportation facilities, including a Texas-New York pipe line, which was considered feasible nine months ago no longer is even mentioned. It has been absorbed by direct war requirements with no prospect of early revival.

This is only one of many examples of the radical change that has accompanied the coming of actual war. During the lend-lease period the obligation of the United States was to furnish the nations fighting Totalitarianism whatever supplies could be spared from the nation's own preparedness program. Now the country is a member of the group of United Nations engaged in that fight and its responsibility is to contribute whatever is needed wherever it is needed to insure ultimate victory for the cause in which America is enlisted. Civilian interests consequently will be subordinated much more drastically than was the case before December 7 if they conflict with military requirements. This will be the governing factor in dealing with existing petroleum transportation facilities.

It is revealing no secret to say that Washington authorities are counting upon the various restrictions applied to the purchase and use of motor cars and their accessories to effect a substantial decrease in civilian consumption of gasoline. If this reduction is not sufficient to bring demand within the limitations imposed by the unavoidable withdrawal of tanker tonnage more direct restrictions will be applied. Meanwhile they are urging and aiding the marketing division of the oil industry to utilize all other possible agencies of transportation to an increasing extent in view of conditions that almost certainly lie ahead.

One favorable factor in the situation is the rising momentum of the shipbuilding program. Additions to the tanker fleet of the United States during 1942 will bring into service some 50 or more new vessels aggregating something like 750,000 dead weight tons. This will be a substantial addition to the tonnage capacity of roundly 450,000 tons in existence at the end of 1941, but it is doubtful whether it will be sufficient to keep pace with the expanding requirements of the war now aggravated by the sinking of several tankers off the east coast with the prospect that further losses of this kind will be sustained.

Warring Nations To Ride On

PETROLEUM RUBBER

By Dr. O. W. Willcox

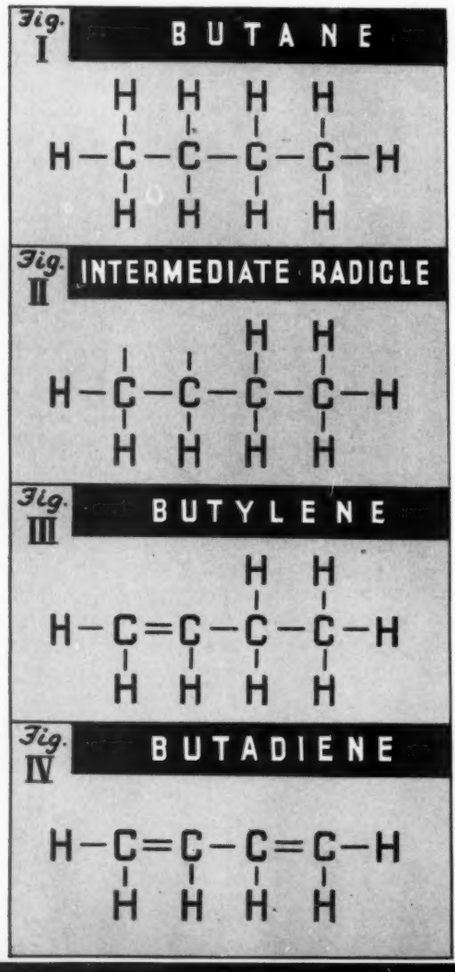
Slow and Cumbersome Process for Production of Artificial Rubber Developed in Germany During World War I—Russians Subsequently Devised More Practical Process Based on Alcohol — Research Program Culminates in U. S. Plans for 400,000 Tons Yearly from Oil.

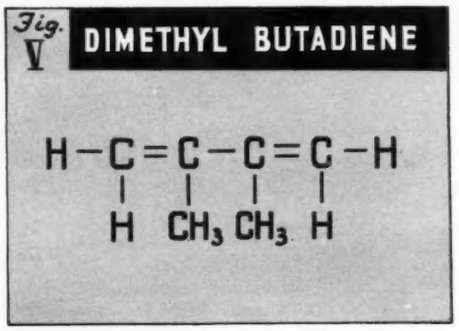
BESIDES OTHER TASKS brought to it by the war, the American petroleum industry is now called on to become the fostering parent of a new and greater synthetic rubber industry. It has stepped into this role out of the fact that it is the one source that can supply the basic materials in any amount likely to be required, in the shortest time and at the least expense. The immediate task is to supply, within the next 18 months, an amount of rubbery material equivalent to 400,000 tons a year of natural rubber. We use the term "rubbery material" because rubber has never been actually synthesized. There is as yet no such thing as synthetic rubber in a strict sense; the numerous products that are called by that name are artificial concoctions which resemble and may even be superior to natural rubber in some respects, but all the desirable properties of the natural product are not found together in any single one of them, although in some the resemblance is close enough for many practical purposes.

The history and present status of artificial rubber—to call it by its right name—are familiar enough to the rubber industrialists. Laymen who wish to see the matter in perspective will find it of interest to review briefly the rise and progress of the idea, and the basis on which it has been developed and is still developing in the United States, Germany and Russia. Ever since chemistry became a real science in the early 1800's the chemists have been exerting themselves to take nature's job away from her. Their method of approach is to learn the molecular construction of valuable natural products, and then literally to build them up in factory processes by the use of cheap raw materials and time saving methods. In this they have scored numerous and important successes; a classic example is the case of indigo, a vegetable product that had become the base of a flourishing agricultural industry which was completely destroyed when it became possible to synthesize indigo at a low cost.

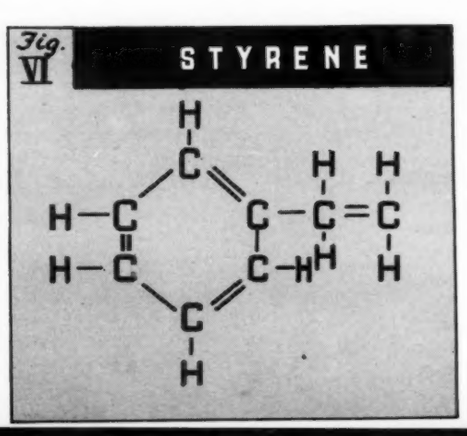
Long before rubber had attained anything like its present industrial importance the chemists began their exploratory dissection of the rubber molecule. After much experimental groping about, they found that the ultimate molecular unit of rubber was isoprene, which itself may be derived from butadiene. Identification of butadiene as the parent material of rubber was strongly supported by the fact that by treating it with heat and catalysts it would polymerize, or coagulate to form a rubbery mass greatly resembling natural rubber. After academic research had arrived at this point, the creation of an artificial rubber industry had only to await the conjunction of three essential circumstances: (1) sufficient knowledge of the properties of butadiene, and of ways to polymerize it into a product having approximately the same mechanical qualities as natural rubber; (2) The discovery of means for obtaining dependable and large supplies of butadiene; (3) The perfection of processes by which rubbery materials could be made from butadiene at a cost that would admit of competition with the natural product.

Since butadiene is now to have a considerable share in the attentions of oilmen, it will be convenient to carry in mind an idea of its nature and molecular structure. It is a hydrocarbon, which is a gas at any temperature above freezing. It has the chemical character of a di-olefin, or diene; it is this dienic character that gives butadiene the ability to function as the parent material of rubbery substances. From a genetical standpoint butadiene is itself a derivative of butane, a common constituent of natural gas. From butane to butadiene there are several steps. Consider first the molecular picture of normal butane as illlustrated in Figure I. In this picture butane presents itself as a chain of four carbon atoms in a row. Each of these carbon atoms has four arms or bonds, one of which binds each carbon atom to its neighbor; the other bonds each hold a hydrogen atom. Suppose that the first and second carbon atoms each lose a hydrogen atom, as could happen when butane is passed through a cracking furnace. The molecular picture would then be as indicated in Figure II. The bonds that formerly held hydrogen atoms are now momentarily free, but this cannot endure: Atomic bonds or affinities must be satisfied somehow, and





Left, molecular changes in the process of transforming butane to butadiene, raw material for artificial rubber: above, structure of material developed in Germany during the first world war for artificial rubber: below, styrene, developed by the Russians, which is now added to butadiene in U. S. manufacture of artificial rubber.



Dr. W. L. Semon, Goodrich research chemist, notes increase of 180 percent in volume of natural rubber after imersion in oil while synthetic Ameripol, at left, shows no effect.

for lack of something else the two free bonds grasp each other, and the molecular picture becomes butylene, as shown in Figure III. Butylene, itself, is a much desired mono-olefin because it is essential in alkylation processes for the production of iso-octane. If the cracking of butane is carried on further to knock one hydrogen atom each from the third and fourth carbon atoms the molecular picture is that shown in Figure IV, or 1:3 butadiene, the parent substance of most artificial rubbers. It is a diene, or an olefin that has two double bonds. These double bonds are weak spots in the molecular structure and confer on the molecules a strong tendency to double up or polymerize to form very large molecules of a peculiarly rubbery nature. The object of the artificial rubber manufacturer is first to procure butadiene and then to induce polymerization.

The first attempt to obtain an artificial rubber for practical use on a large scale was made by the Germans during World War I. The Germans had no practicable way of making butadiene, so they selected what appeared to be the best available substitute, dimethyl butadiene, a diene which has the molecular picture shown in Figure V. This is butadiene with two methyl groups in the place of two hydrogen atoms. To get this material the Germans had to start with expensive acetone and put it through an expensive chemical process. The dimethyl butadiene has two double bonds and hence like other dienes, has a facility for polymerizing to make a rubbery material which was christened methyl rubber. It turned out to be an unsatisfactory imitation of natural rubber, but such as it was the Germans managed to bring production up to 300 tons a month. When supplies of natural rubber again became available the production of methyl rubber was promptly dropped as it was unable to compete with the natural product.

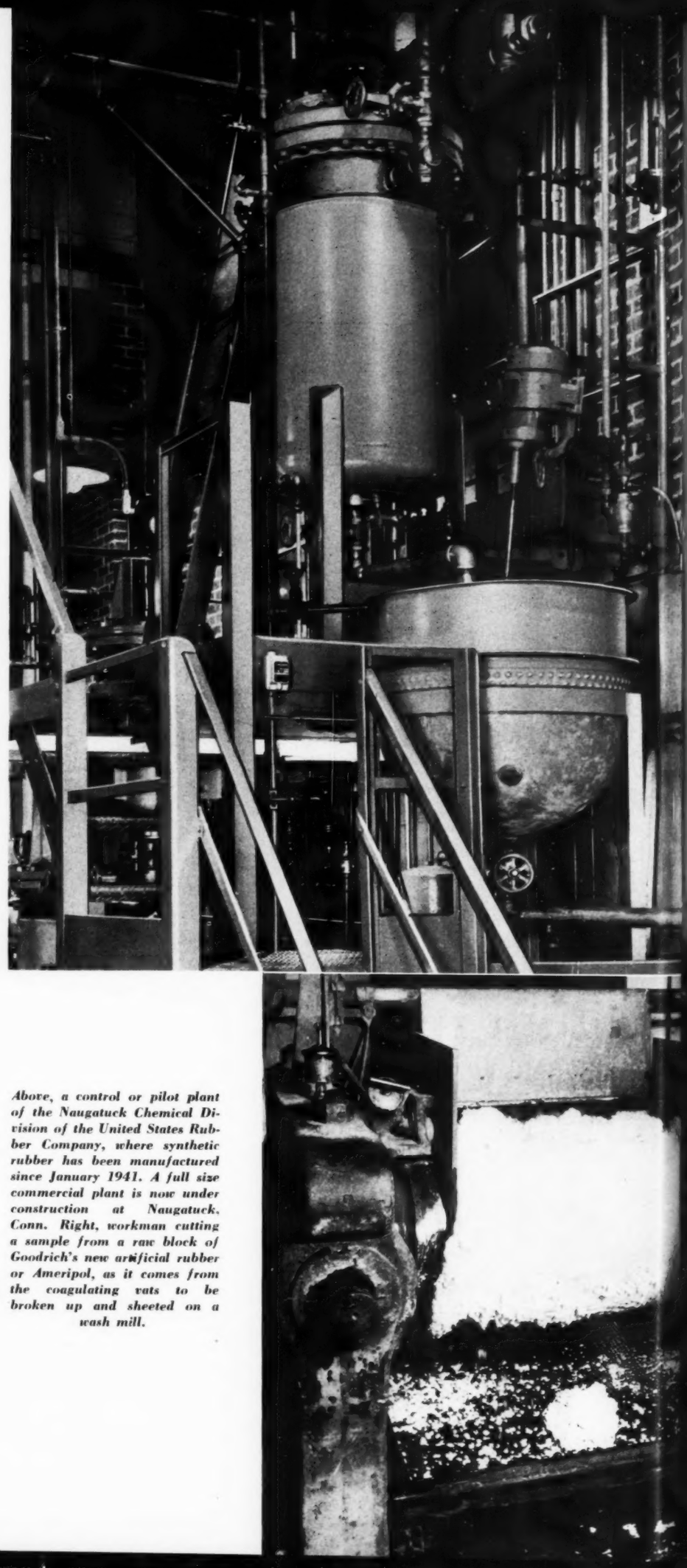
Little or nothing was heard about artificial rubber for about ten years, when the British inaugurated the Stevenson restriction scheme through which the price of natural rubber was hiked above a dollar a pound. This was a strong incentive to reopen the matter of rubber substitutes. This time the Germans adopted a process by which butadiene may be made from limestone and coal—raw materials which they possess in unlimited quantities. At that, the process is an expensive one, involving numerous steps. First, lime and coke are heated together to form calcium carbide. Next, the carbide is decomposed with water to form acetylene. Then acetylene is oxidized to make acetaldehyde; the acetaldehyde is polymerized to form adol: Adol is reduced with hydrogen to make butylene glycol which is then dehydrated and the product of that operation is butadiene, with which the manufacture of artificial rubber is then begun. A product thus obtained would have no chance of competing with reasonably priced natural rubber in a free market. But as we of the United States are now learning, military necessity knows no economic law; so the Germans have adopted this expensive and roundabout method to meet the needs of their war machine. They cannot obtain butadiene from petroleum, because they need every drop of petroleum they can get their hands on for other purposes, and much of what petroleum they have has itself to be made artifically at an uneconomic high cost. Compared with what is now demanded of the artificial rubber

Synthetic rubber plant at Baton Rouge, completed by Standard of Louisiana as part of the rubber program for the war effort. Photo by Robert Yarnall Richie.

industry in the United States (400,000 tons a year), the corresponding German industry is on a small scale. Just before the war, one German factory with a capacity for 25,000 tons was in operation at Schkopkau, and shortly after hostilities opened another of similar capacity was opened at Huels. It is understood that German production is now about 100,000 tons a year, or about as much as is normally consumed by one leading American rubber company.

Although the Russians have been giving much attention to the exploitation of native rubber-bearing plants, and apparently with some initial success, at this moment they, like the Germans, are relying for most of their needs on artificial rubbers made from butadiene. However, they do not obtain butadiene in the same roundabout way as the Germans, but have developed a simple and direct process using alcohol. By passing vapors of a mixture of alcohol and acetaldehyde (itself made from alcohol) over a suitable catalyst it is possible to dehydrate and rearrange these substances to form butadiene in a single operation. Recently this process has been simplified by dispensing with the direct use of acetaldehyde. In the new Russian process vapor of alcohol alone is passed over a catalyst of mixed aluminum and zinc oxides at 400 deg. C. Under these conditions the necessary acetaldehyde is formed and consumed in the course of the reaction. This comparatively easy process is beyond the reach of the Germans because the latter need more than all the fermentable materials they have for food and for the manufacture of alcohol for making powder. The use of alcohol by the Russians as a prime material for artificial rubber may appear a little strange in view of the fact that Russia has immense supplies of petroleum hydrocarbons from which butadiene might be made more cheaply. Whatever the explanation may be, it appears that the Russians will now be obliged to fall back either on carbide or on their petroleum resources, because the area producing sugar beets, the chief source of fermentable sugar, has been overrun by the Nazis and the sugar factories and distilleries presumably dismantled. The annual production of artificial rubber in Russia has been reported as 100,000 tons, or about the same as in Germany.

Although procurement of suitable raw materials for making butadiene was an outstanding problem in the early stages of the artificial rubber industry, the problem of transforming the butadiene into a rubber substitute offered difficulties that were overcome only after a long series of researches in which numerous investigators in various countries made contributions. Butadiene becomes rubbery only after it has been polymerized; the trouble was to find a workable means of inducing polymerization. Long heating in the presence of acids or catalysts would effect polymerization, but aside from the long time the product did not make a close enough approach to natural rubber. Then it was discovered that better and quicker results could be obtained by



Above, a control or pilot plant of the Naugatuck Chemical Division of the United States Rubber Company, where synthetic rubber has been manufactured since January 1941. A full size commercial plant is now under construction at Naugatuck, Conn. Right, workman cutting a sample from a raw block of Goodrich's new artificial rubber or Ameripol, as it comes from the coagulating vats to be broken up and sheeted on a wash mill.

using metallic sodium as the polymerizing catalyst. This discovery not only shortened the time, but gave a product that more nearly corresponded to real rubber and laid a foundation on which Buna rubbers could be produced. "Buna" it may be noted, is a coined word composed of the first syllable of butadiene and the first syllable of natrium, the Latin word for sodium. Even so, the process was still inconvenient and time consuming since polymerizing the butadiene with sodium had to be done in batches. Then it was found how to make the process continuous, and the continuous process is now used exclusively. The butadiene or material containing butadiene is fed into a solution containing emulsifying materials and the mixture thoroughly churned up to make an emulsion of creamy consistence which flows continuously through a heating zone where polymerization takes place. The rubbery mass is then separated from the liquid. But it was eventually found that although butadiene is indubitably the ultimate structural unit of rubber, the manner in which it polymerizes to form natural rubber is still nature's secret. The rubbery materials obtained by polymerizing butadiene alone were far from satisfactory. However, acceptable material could be obtained by first mixing the butadiene with other materials and then polymerizing. The most suitable materials for this purpose turned out to be hydrocarbons which have one or more double bonds with which the double bonds of butadiene could polymerize. This is copolymerization, or the polymerization of various substances together. The discovery of copolymerization (which was made by the Russians) opened up a way to produce an almost unlimited range of concoctions having rubbery characters with a butadiene base. However, only a few of these have become of practical significance. Chief among these is a product known as Buna S, which is now the main reliance of the German artificial rubber industry, and is the one that will figure most prominently in the new American industry. Buna S is a copolymer of butadiene and stylene. The latter is more intimately known as phenyl ethylene. Its molecular picture is shown in Figure VI. It may be regarded as a fusion of benzene and ethylene, both of which are well known to the petroleum industry. Benzene is formed in the same cracking process that gives rise to toluene. The manufacture of toluene is also one of the new tasks committed to the oil men, and the two may be more or less easily produced from the same charging stock and cracking process. The Buna S type is the one that combines the nearest approach to natural rubber with the lowest cost of production, which is said to be no more than 30 cents a pound under present conditions and the state of the art. The preferred mixing formula for Buna S is for three parts of butadiene and one part of styrene. These proportions give a product that has the best resistance to heat and abrasion. There are two other Buna types that the Germans have industrialized: Perbunan, for use with oils, and Buna 85, for very hard rubbers, but the Germans lay far greater emphasis on Buna S than on any of the others. After butadiene and styrene have been obtained at the oil refineries, they may be delivered to the rubber manufacturers, although it is understood that some of the oil companies that are arranging to produce the raw materials will also attend to the polymerizing. In any case, final fabrication is a matter for experienced rubber manufacturers. Among the many differences between the natural and the artificial product is difference in workability. The artificial products are far more difficult to "masticate," for which powerful special machinery is needed, but once masticated they can be compounded, softened, filled and moulded in much the same way and with the same materials as natural rubber. One of the best softening agents for artificial rubber is a small proportion of natural rubber, which offers one method of making a limited supply of the natural product go a long way.

While the Germans and the Russians were exploiting butadiene as a more or less satisfactory substitute for natural rubber, an artificial rubber industry was taking root in the United States. But the approach in this country was quite different from the European approach. In Europe artificial rubber had to be made as a complete substitute for the natural product, which was more or less difficult to obtain. In the United States the ruling idea was not to find a substitute for natural rubber, which at all times could be had in free supply at reasonable prices, but to obtain rubbery materials that could be applied to uses for which natural rubber was distinctly unsuitable. For instance, natural rubber has only a fair resistance to heat, and tends to deteriorate when used in situations where much heat is developed. Again, natural rubber has little resistance to oils and hence is subject to deterioration when used around greasey machinery, especially where there is heat. So the American chemical industry started out (du Pont taking the lead with neoprene) to make a rubbery product that would fill a want which natural rubber cannot meet, and which would sell on its own merits. As a matter of fact, these rubbers, of which there are now numerous types on the market, are freely bought for special purposes at prices very much higher than are paid for natural rubber, and even before December 7, 1941, were being produced on a large tonnage basis. But neoprene, thiokol and other special type artificial rubbery substances are not the best answers to the demand for automobile tires. For this and related purposes Buna S is still the best choice after natural rubber. The call now is for butadiene as the base material from which American industry is to produce the closest equivalent to 400,000 tons of rubber a year. So far as concerns the oil men the problem is one of finding the necessary butadiene, and the terms and limits of this problem are now well defined and allowed for in the great plants that are being erected.

There are two prime sources of butadiene. One is butane, a very familiar component of natural gas and light distillates. But there is the difficulty that butane is also required for making 100 octane number gasoline. How are both these demands to be satisfied from the same limited source? In a recent study by W. N. Nelson it was pointed out that the petroleum industry has been using 40,000 bbl. of butane a day and wasting 15,000 bbl. for which it had no ready market. It is now up to the natural gas industry to recover more of this wasted butane by using more absorbing oil. Butane cuts should be taken from stabilizers and fractionating towers. How much butane will be needed to make 400,000 tons of artificial rubber is not yet clear to the experts, but Mr. Nelson is of the opinion that the natural gas and refining industries can and should furnish 20,000 bbl. of butane fractions a day, which presumably will take care of the demand in the initial stages. Beyond that the industry must begin to crack gas oil or light gasoline fractions, using special catalytic cracking processes to obtain maximum yields of low-boiling olefins and dienes for separation and copolymerization. Once butane is obtained it is relatively easy to subject it to a gentle cracking that will give a good yield of butylene. Methods are now known whereby butylene may be further catalytically cracked to give a 79 percent yield of butadiene.

At the most, the problem thus handed to and accepted by the oil men is not of stunning proportions, relatively speaking. One days' production of crude oil if used solely for rubber, will take care of the whole supply. The problem is one of detail and the saving of that portion of the crude oil and natural gas that should go into rubber and aviation gasoline, and in this saving all natural gas plants and refineries may take part. It will be necessary that a majority of these plants should be included in the broad overall plan: apparently it will not be sufficient to depend solely on the major refining centers.

IMPORTANT RESERVES MAY EXIST IN SEDIMENTAR ST

By Norman C. Smith

Diminishing Returns from Current Exploration Techniques Suggest Careful Consideration of Possibility of Petroleum Accumulation Under Other Than Structural Control —The Accompanying Article Concentrates on Sedimentary Structures Bounded by Porosity Variations as Contrasted to Tectonic Structures that Heretofore Have Attracted Almost Exclusive Attention of Petroleum Geologists—Without Suggesting the Use of New Exploration Methods, the Author Proposes a More Exact Examination of Possible Accumulations Under the Control of Primary Sedimentational Features Alone.

"It is my opinion that there are enough undrilled but known prospects, and there is enough territory not yet fully examined by the seismograph to maintain the current discovery rate for the next five years or so. Beyond that the discovery rate must depend on the skill which we develop in searching for stratigraphic traps and upon our success with new techniques such as electrical methods or soil-gas surveys, or upon either of them. We are undoubtedly somewhere near the end of our whole structure-finding type of prospecting."—E. De Golyer.

The author, Norman Cutler Smith, who developed the accompanying theory while engaged in research on sedimentation and petroleum, under Dr. Joseph A. Cushman. Mr. Smith obtained his A.B. degree at Washington and Lee University in 1937 and spent two years as geologist for the Standard Oil Company of Venezuela. He is now a teaching fellow at Harvard in the petroleum geology courses.

THE war-time requirements of the United States and its allies place a grave responsibility upon the petroleum industry. It is expected that the recent considerable demand for crude petroleum will be so greatly increased as to deplete seriously our known resources. Therefore, we are compelled to investigate the possibility that our currently successful methods of exploitation must eventually be outmoded by the exhaustion of known structures and the steadily diminishing number of those yet undiscovered as suggested in the foregoing quotation from Mr. DeGolyer.

Within the last year leading geologists have expressed the opinion that field geology, as a technique for the discovery of oil fields, has not only passed its peak but has practically exhausted its usefulness except in foreign work. If there has been an evident decline in the use of field geology in the search for petroleum, such a lapse is due to mental rather than physical limitations. The collective mind of the petroleum industry has developed what might be called a "structure complex." This peculiar mental state is characterized by a skepticism which inhibits the power of that mind to conceive the thought that petroleum might accumulate under other than structural control. And yet, petroleum reservoirs owing their existence to sedimentary conditions have supplied a major portion of this country's production apparently without causing enough curiosity among geologists to provoke more than a casual study.

A rapidly increasing number of workers are of the opinion that significant factors in a successful future for the oil industry are surer understanding and more intensive application of the principles of sedimentation to the problem of prospecting for oil. A revision of the prospecting methods to suit the already developing trend will establish the objective of conducting more detailed geological surface studies than have been made in most areas in the past. Such a program does not involve the introduction of any new criteria or methods except as refinements and redefinitions of the old principles prove essential to more exact work. The program does, however, entail the confluence of well known principles of geology, geochemistry and geophysics under a new emphasis—the significance of primary sedimentational features with regard to petroleum accumulation. The fundamental principles concerned with a study of features in this category are those related to transition in character between the deposits of related environments. A thoughtful perusal of the fundamental criteria for petroleum accumulation provokes the suggestion that one, at least, might be examined and further interpreted. It is apparent that the accumulation of petroleum requires the existence of geologic structure suitable for concentrating oil in commercial amounts. *Geologic structure* has been taken by prospectors in the past to refer specifically to what might better be designated *tectonic structure*. It is recalled that the term *geologic structure* is, by definitions amplified significantly to include structures owing their origin to sedimentary as well as diastrophic causes, and this distinction is herein retained. Thus, the possibility should be considered that favorable conditions for the accumulation of substantial amounts of petroleum exist under the control of primary sedimentational features alone. Establishing the fact of their existence and granting accessibility to migrating petroleum, we should further be concerned with the objective attributes of such features as may aid in devising feasible procedures for locating such petroleum.

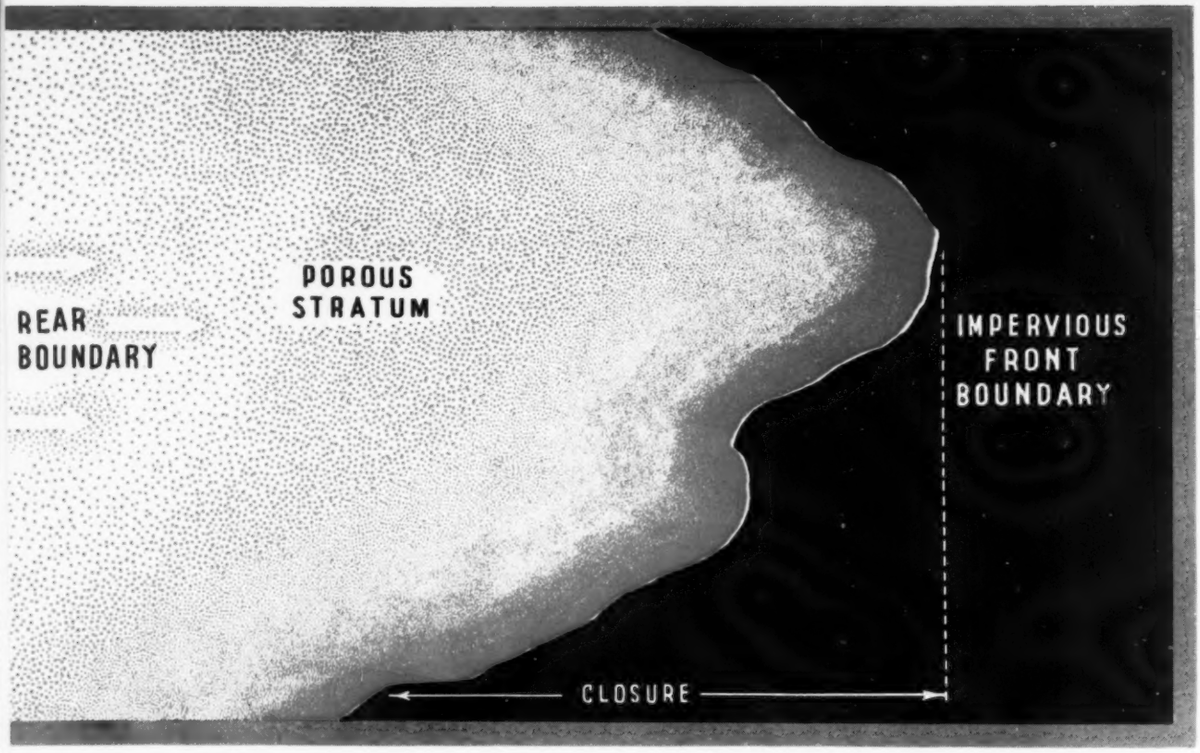
Among original sedimentary structures, the characteristics of which are directly traced to the mode and environments of deposition, the following may be listed: pinching beds, lenses, reefs, porosity variations due to grain size and porosity variations due to other primary sedimentary causes. Pinching beds, lenses and reefs have already been shown by many writers to

Idealized diagram of a vertical section thru a potential oil trap, operable in a porous stratum through the confinement provided by non-porous strata above and below, and an impervious lateral facies. Arrows indicate the direction of oil movement into the trap, the impelling forces serving as a mobile "rear boundary", causing the petroleum to be impinged against an impervious "front boundary" formed by the introduction of fine-grained sediments during deposition of the stratum.

account for considerable accumulation of petroleum in fields which are primarily controlled by anticlinal and faulted structures. It is presumable that, where pinching beds and lenses are developed on a scale subordinating the influence of folds and faults, and where the supply of migrating petroleum is sufficient to fill the porous strata accumulations of petroleum may occur which are of proportions to endow long life to the wells that tap them. However, it is sedimentary structures indistinguishably bounded by porosity variations not readily apparent to cursory examination with which the writer is primarily interested. The formation of such structures is inseparably connected with the sedimentational phenomenon of facies change.

Wishing to avoid treatment of sedimentational principles with which most geologists are more or less familiar, the writer prefers to supplement a few necessary remarks with references to the best literature on the subject listed in the bibliography at the end of this article. Deposits laid down along either the seaward or landward sides of the strand line produce rocks least likely to contain depositional units that are uniform in texture throughout any great areal extent. Considerable and irregular ranges of grain size and rapid changes in thickness are typical developments in beds of the shoreward portions of the neritic zone and adjacent areas. Normal deposition is frequently interrupted by the agency of wind or tides so that inter-stratified sands and muds are particularly common. Disruption of previously-laid deposits by storms and unusually deep-reaching waves and currents permits the development of complicated inter-enveloping lentils of sand and mud. Within a single deposit rapid gradation is often developed with relation to the arrested competancy of the transporting currents. In general, the coarser sediments are adjacent to the shore and grade seaward into finer sediments. Although the exceptions to this generalization are many, they do not in any way detract from the significance of load and water-competancy as operating in shoreline areas. The anomalous occurances typically reveal a similar textural gradation in a direction other than normal to the coast, and are indicative of the variously directed currents which cause them. Rapid changes in the character of the lithology and faunas represent the fundamental conditions most typical of neritic deposition in open and continental marine areas. It is this environment, therefore, which we would expect to produce rocks containing primary sedimentational structures significant to this study. Furthermore, experience has taught that the strata of this origin are most commonly associated with migration and accumulation of oil and gas and, as far as we know at present, with their source. The development of lenses, pinching beds, and grain size variations within the strata unquestionably have an important bearing on the migration of oil, and may concievably be found to involve effective barriers for petroleum accumulation.

Just as the lithic character of deposits is controlled by environmental factors, the floral and faunal constitution reveals a similar response to the impinging influences of environment. The sum total of organic remains preserved along a geologic horizon, recording adaptive responses of an organic congregation to a single environment, may be called a biologic facies. The realization that variations in environment produce corresponding variations in the lithologic and biologic character of a deposit has brought to the stratigrapher an indispensible tool for stratigraphic interpretation. Such changes of facies occur in every geologic system, and are most spectacularly developed in the general vicinity of the strand line, where marginal deposits grade laterally into non-marine. The changing sequence may be followed in all directions from a point of observation: laterally and vertically from marine to continental beds; from shallow marine to deeper marine. The most significant observation to be made from the available information is that the localized nature of the environmental influences operating in depositional areas is directly reflected in a corresponding localization of internal textures within sedimentary rocks. The arrangement of the particles which comprise a rock, as



Idealized diagram showing horizontal plan-view of a potential oil trap. Arrows indicate the forces impelling the oil to be concentrated against and within the arc formed by the extended wings of the impervious "front boundary." The arcuate contour of the "front boundary" is a primary feature, developed during deposition of the stratum. The structural term "closure" is tentatively applied here to classify the stratigraphic concept by analogy.

well as their assortment and shape, bears directly upon the porosity of the rock as a unit. In general, it may be said of grains that the greater the angularity, the greater the sorting, and the less the orderliness of arrangement, the greater will be the porosity. The close control of these factors on porosity immediately suggests the exceedingly great variation in permeability, both abrupt and transitional, that exists among sediments where a change of facies is represented. Another observation of equal importance pertains to the presence of colloids which reduce the permeability of a formation without necessarily decreasing the porosity, through the agency of absorption. This point is brought out in a paper on Electrical Well-Logging by the Houston Geological Study Group, published in Vol. 23 (1939) of the Bulletin of American Association of Petroleum Geologists.

It is unnecessary to review here the various processes which are currently believed to account for the migration of oil and gas through porous strata. Neither verification nor evaluation of these processes are germane to the problem at hand, the essential point being that migration of oil does occur both laterally and vertically within the limits established by certain internal forces. It is considered significant to the reasonableness of this particular supposition that all of the known forces causing the movement of fluids through buried strata may be calculated to act singly or in conjunction without in the least compromising the efficacy of sedimentary barriers to render them inoperable.

We have remarked, within the limits of reasonably certain knowledge, the interaction of environmental factors believed to influence the deposition of sediments which, when buried and consolidated, are characterized by great variations in porosity and, therefore, equally great variations in permeability. Further, it has been determined that such variations, being common, must exercise a profound influence upon the movement of fluids within buried strata. From such generalized studies it is desirable to proceed to a more specific discussion of the sedimentary structures which may be expected to harbor commercial amounts of petroleum. Although reservoirs of this type may have already been typed, geologists, eager to apply the familiar definition of anticlinal and faultline control, have failed to interpret the sedimentary features present. Therefore, in dealing with this portion of the problem we enter upon a speculative phase of geology regarding essentially unexplored types of traps suitable for petroleum accumulation.

If we are to determine what constitutes a trap, structural, sedimentary or otherwise, we must establish the existence of conditions which lend themselves to a stricter confinement of fluids than is implied by the term *barrier*. To accomplish effectively the accumulation of oil for an indefinite period of time, a trap must possess boundaries in three dimensions or, it may otherwise be stated, its boundaries must prohibit the passage of oil in all directions. It is a foregone conclusion that its size must permit the concentration of sufficient amounts of petroleum to be commercially producible. Any porous stratum which is bounded above and below by imprevious beds is a potential trap. Its potentialities are further enhanced by the existance of boundaries, in a plane perpendicular to the impervious layers, which may represent the impoverishment of porous zones within the stratum. Thus, the forces which impell the migration of oil and gas in some lateral direction may be considered to function as a front boundary. Whereas it is apparent that the migration of oil into an environment so delimited will be impeded from further advance in the same direction by the presence of an impermeable barrier, it is likewise discernible that, unless the barrier is in some way modified from rectilinearity by innate configuration, the propelling pressures may be resolved to operate in the same plane but at angles to the line of original movement. Obviously there must be lateral boundaries to insure the complete and more or less permanent confinement of the petroleum, and the lateral boundaries might well be formed by the extention of the wings of the barrier to form a "curved plane", as in a truncated hemicylinder. Therefore, in estimating the value of primary structures as natural oil reservoirs, we are fundamentally interested in those which exhibit characteristics adaptable to this conception of an effective trap. With regard to the essential boundaries which delimit a trap, primary sedimentary structures may be considered analagous to anticlinal structures for the purpose of clarifying the conception outlined above. Thus, we may speak of closure when referring to the distance between the lines that mark the effective limits of the impermeable zones barricading the oil within the porous area of a given horizon.

A description of the conditions under which a hypothetical structure might be formed may stimulate the speculative powers of the reader. It is at least interesting to observe the alternating arcuate concave and convex contours which characterize most shorelines. In this connection, H. Leypoldt, states in "Shore and Beach," (Vol. IX, No. 1, 1941) that littoral oceanic currents induce eddy currents in the lee of promontories, either natural or artificial, and thereby shape the shorelines to some form of the logarithmic spiral, $r - e^a$. One notes that such a configuration is best developed along mature coasts, particularly those of interior seas, where

embayments and inlets are common. Rivers, emptying their loads into standing water, naturally lend impetus to the momentum which tends to carry the river-material seaward in a direction largely determined by the point of debouchure upon the curvature of the shoreline. Presumably there is a tendency for the arcuate character of shorelines to be extended seaward, finding expression in a like delineation of the sediments. In the case of the convex portions the arc is transmitted along diverging lines which tends to increase its size. The accurate nature of the concave portions is similarly transmitted but along converging lines which tend to decrease its size and accentuate its form. On being supplied to a basin of deposition, detritus tends to segregate itself according to the size of the constituent particles. The water in the basin acts as a sorting agent with the result that the average size of particles settling out becomes less the further the particles are removed from the source of supply, and the more symmetrical the size-distribution of the particles becomes. Therefore, it is further supposed that such curved forms will be related to the general grain-size distribution of the sediments, and at some unpredictable locality may actually determine the outline of impervious zones. Should sedimentary studies prove that these tendencies do operate in nature, it may be stated that here exist pontential sedimentary traps for the accumulation of petroleum.

One immediately thinks of the Burbank Field in Oklahoma which is featured by the occurence of irregularly placed and shaped porous portions in the producing sand. It is posible that the irregularity, which has never been satisfactorily explained, is only apparent and the limits of permeability may conform to some more or less definite configuration such as has been described. A similar explanation might clarify the conditions of oil accumulation in the Glenn Pool of the same state. It is noteworthy that at the Glenn Pool there has been no production of importance where the sand is less than 25 ft. in thickness, suggesting that impermeable zones may have been developed during deposition, possibly with the introduction of high percentages of clay particles and colloids. It should be pointed out that these two fields, in which sedimentation is known to exercise primary control upon accumulation and whose productions are rated among the largest in this country, establish beyond all reasonable doubt that the proposed search for sedimentary structures need not be resigned to finding minor quantities of oil.

It may also be considered that the varied effect of currents upon the near-shore deposition might well be responsible for the development of impervious facies distinguished by curved outlines. When the particles of sediment encounter water moving with a significant velocity in the course of their transportation through the water in the environment of deposition, the normal order of deposition is altered. If the bottom of deposition is separated from the moving water by an intermediate zone of quiet water, then during periods of rapid motion the fine particles will be washed away and only the coarser constituents will descend into the quiet water below to be deposited on the bottom. If, on the other hand, the moving water bathed the sediments, it would agitate them, with the result that during periods of rapid movement fine particles will be washed away. In either case the resulting bottom deposit should be relatively coarse and fairly well sorted, forming a porous structure which might later become an excellent avenue of migration for petroleum and gas. The particles that are prevented from being deposited because of the motion of the water tend to remain in suspension until the velocity of the water is checked. As the movement of the water progressively diminishes, finer and finer particles will settle to the bottom. The sediments in such areas of deposition derive their constituents from two sources; the normal supply in the water, and the particles transported from the region of moving water. The deposits therefore, should be poorly sorted and should have an unsymmetrical size-distribution transformable into rock with low porosity and permeability.

If the moving water which alters the original course of the suspended sediments constitute a littoral current, conditions may be conceived to operate in the area of diminished grain-size which will investigate the curvation of a depositional zone, later impervious to migrating fluids. A littoral current sweeping by a projecting headland will cause the formation of eddy currents moving in the opposite direction along the inner edge of the inlet as described by H. Leypoldt in the January, 1941 issue of "Shore and Beach." The seaward borders of the littoral current will be impeded only by the friction generated against the relatively quiescent ocean water, and the central portions will attain a maximum velocity, determining that deposition of a restricted range of the coarsest particles is maintained along the bottoms over which they pass. The innermost portions of the littoral current and the central portions of the eddy current will be subject to a

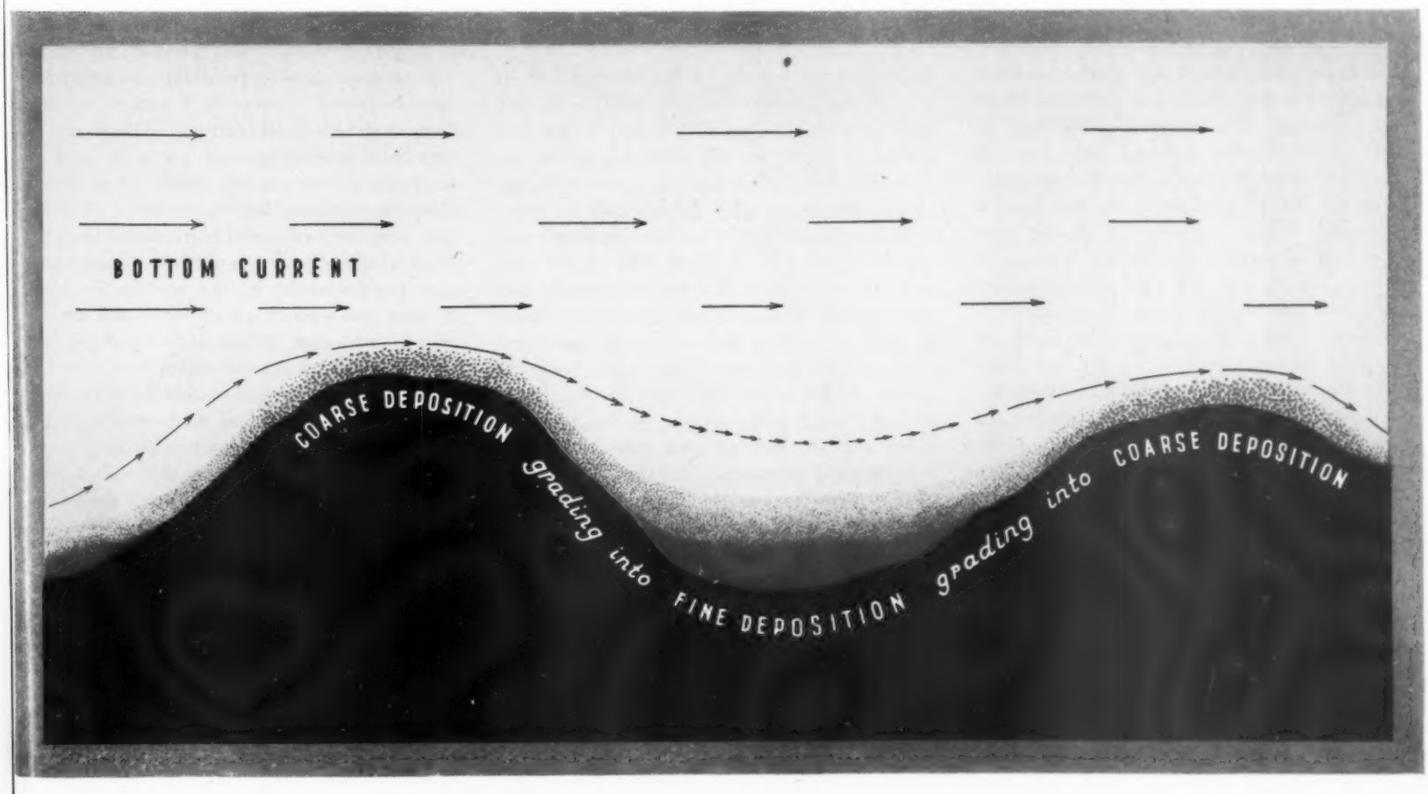


Diagram illustrating initial depositional tendencies developed where bottom ocean currents move across an irregular floor. Arrows indicate the relative velocities of various levels of the current; —maximum velocity maintained above the ridges allowing coarsest deposition to occur there; the water in contact and near the floor is retarded, allowing the finer constituents to accumulate in the depressions. Corresponding to the current gradient, the deposits reveal a gradation in texture from coarse at the summits of the ridges, through transitional phases along the slopes, to fine in the bottoms of the depressions.

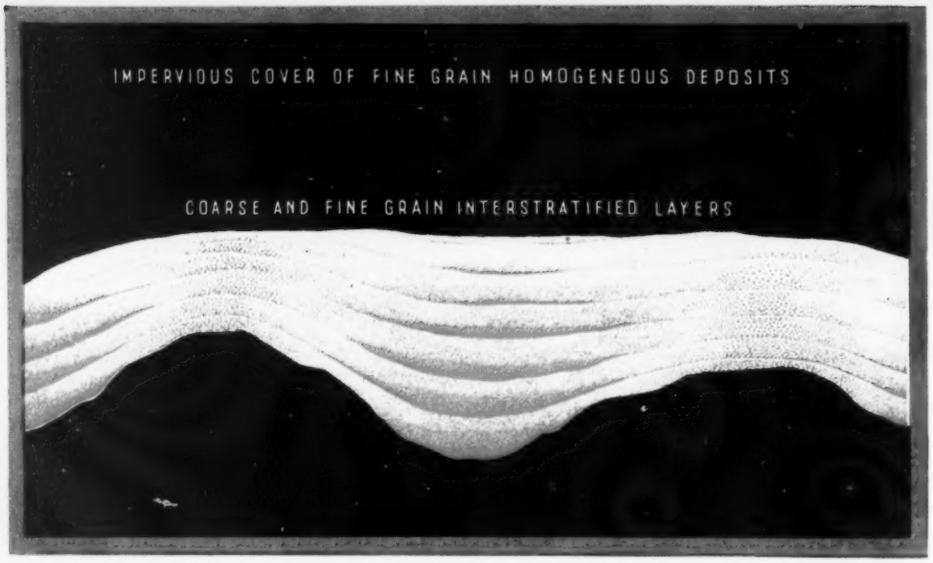


Diagram showing a series of strata which might develop if the conditions shown on page 33 were to be maintained for a sufficiently long period of time. The finer muds collected in the depressions successively overlap the coarser deposits accumulating on the ridges. The depositional tendency to smooth out irregularities of the sea-floor is gradually materialized and the series of deposits is finally capped by an approximately horizontal impermeable layer. When consolidated the sands are transformed into sandstones and the muds become shales, providing a favorable path for migration and traps for the accumulation of petroleum.

comparatively greater impedance due to the reversed direction of the shoreward portion, causing a check in the velocity of the water and resulting in the deposition of the finer particles of sediment. The occurance of selective deposition in this environment will effect the formation of impervious zones in a linear arrangement, a curvature being imparted by the source of the eddy current. These two conjectural examples must suffice to illustrate the influences of both shoreline and currents which might combine to create unlimited numbers of natural traps in the internal structure of near-shore sediments. The uncertainty in the question of their actual existence speaks for the vast amounts of research which must be accomplished before the principles are well understood. It seems desirable to pass on to a discussion of other possible causes of sedimentary anomalies which might serve to arrest petroleum migration.

A subtle and profound influence on the deposition of sediments is that practiced by submarine topographic control. This subject is discussed by P. D. Trask in the January, 1931 issue of "Economic Geology" and by Revelle and Shepard in the AAPG publication "Recent Marine Sediments". Where a change in the sea level has quickly submerged considerable portions of the coast, the floor of the area of deposition is very uneven and consists of a series of ridges and depressions. Some of the ridges may rise above the surface of the water to form islands, and many of the depressions are closed basins. Divides between the basins tend to obstruct and deflect the course of currents causing the velocity of the bottom-moving water to be greater over the ridges than on the slopes and in the depressions. Due to the internal friction of the water the strength of currents immediately overlying the sea bottoms should decrease progressively from the ridges into the valleys. As the texture of the sediments depends, among other things, upon the velocity of the water in which they accumulate, it follows that the degree of fineness of the deposits should increase progressively from the crests of the divides towards the bottoms of the valleys and basins. It is apparent that the maintenance of these conditions will result in the deposition of appreciable thickness of coarse-grained layers parallelled by the successive deposition of fine silts and clays. If the cessation of differential deposition were to be featured by the placement of an impermeable shale covering, it will be seen that a trap has been formed that will effectively collect oil moving into the porous strata. In fact, any gently rolling surface may lend its arching contours to the bedding of the sediments deposited upon it, thus allowing the irregular strata to function for oil accumulation in much the same manner as if they were folded by compressional stresses.

An important feature in the development of facies is the formation of intercalated beds. Such bodies may be the result of a normal series of events: (a) exposure and dissection of the uppermost sediments laid down by a retreating sea; (b) further reworking of the debris by the waves of the re-advancing sea; (c) final deposition and burial, representing the first beds of the new invasion, intercalated between the previous and later formed marine strata. The stratigraphic relations of such sands will be characterized above and below by transition into the finer sediments of deep-water deposition. Although the vertical change in the texture of the sediments is not representative of true facies change, it is a related phenomenon. However, a favorable porosity may be maintained laterally in the intercalary to the convergence of the impermeable beds, and in this same facies change may be said to offer an effective trap for oil accumulation. Further speculation along these lines can accomplish no more than has already been done to suggest a few of the more obvious primary sedimentary traps for oil, though it may profitably be continued at a later date when accurate and detailed information is at hand. If we may agree, however far from verifiable fact the exercise of our imagination may have led us, that sedimentation wields a more tangible control over the accumulation of petroleum than has generally been suspected, than we are faced with the puzzling problem of locating such accumulations for the drill and ultimate commercial production.

It has been observed that, while sedimentary traps of the type herein described may function in a manner somewhat analagous to that of anticlinical traps, yet they differ in the essential properties which actually cause petroleum to accumulate. Whereas undulations of warped strata lend themselves to detection by various prospecting devices operated upon the surface of the ground, the variations of porosity which characterize the sedimentary traps are of a more recondite nature. It is apparent that the fundamental approach to the problem of determining the localities of favorable sedimentary phenomena is through a study of the environmental influences upon which their formation is contingent. The significance of this truth is to place an emphasis, which can neither be too forcefully expressed nor too completely comprehended, upon the importance of trained observation and intelligent speculation as necessary attributes of a successful prospecting program of the future. It might be here reiterated that the attitude herein expressed must not be construed as favoring a clean-sweeping substitution of the valuable exploration principles that have evolved through long experience. Rather it should be understood to advocate a rejuvenation in the application of these principles by the injection of new objectives. Every one of the various current field techniques constitutes an invaluable aid to the detailed translation of the stories hidden in the rocks. Exactly how each technique may be used in its present state, or how modified, must be the task of the experts to determine when they have been furnished a more lucid outline of objectives and significant criteria. The future of petroleum prospecting may safely be predicted to involve a more intense application of geology than the profession has yet witnessed. Although new principles and methods are almost certain to be developed, the first work to be accomplished is a re-examination of the inestimable wealth of data contained in all of the well cores and records, geological surface studies, and geophysical and geochemical surveys that have ever been made. The new interpretation of the old material must place an emphasis on the factors relating to sedimentation and the operation of its principles in the geologic past. As new material is forthcoming, it likewise must be subjected to the same close scrutiny and interpretation.

All sediments, continental or marine, are related to the regional environments of their deriva-

tion, transportation and deposition. These relations must be sought out and studied for the purpose of reconstructing the conditions which have prevailed in the past. In addition to resolving the pure geology, this objective must result in perfecting a thorough knowledge of what has been called by Dr. W. L. Whitehead, "paleogeomorphology". The term, though used facetiously, aptly connotes the wide scope which must be covered by the projected studies. Maps and charts should be constructed on the basis of the obtainable data so that the physical conditions of the past are as familiar to the geologist as the view from his office window. When the information is thus in hand, and only then, we may begin to draw intelligent conclusions concerning the effects of sedimentation. The continuance and stimulation of stratigraphic studies is essential to building the new geology, and in this phase of the work sedimentation and paleontology are combined requisites to understanding the significance of lithologic facies. Greater activity in the fields of sedimentary petrology and minerology is needed to further the skill of deciphering the complexities of sources and climates. A mineralogical method which is still in the introductory stage, but which must eventually become an invaluable tool, is spectrographic analysis. Spectrographic studies should be conducted with regard to fragmental minerals for determining the sources of sediments. Similar analyses of colloidal minerals held in suspension in crude oils may lead to the discovery of their sources, mechanical analyses of sediments and porosity-permeability studies must likewise continue to clarify the physical character of sediments and their all-important bearing upon the conditions which control petroleum accumulation. Information derived from these sources might profitably be assigned to draughting isopore and isoperm maps so that the porous and nonporous areas might be visually represented in areal distribution. All of these and other methods are barely suggestive of the manner in which field and laboratory must reach an amicable cooperation which will best serve the profession as a whole in locating petroleum reserves.

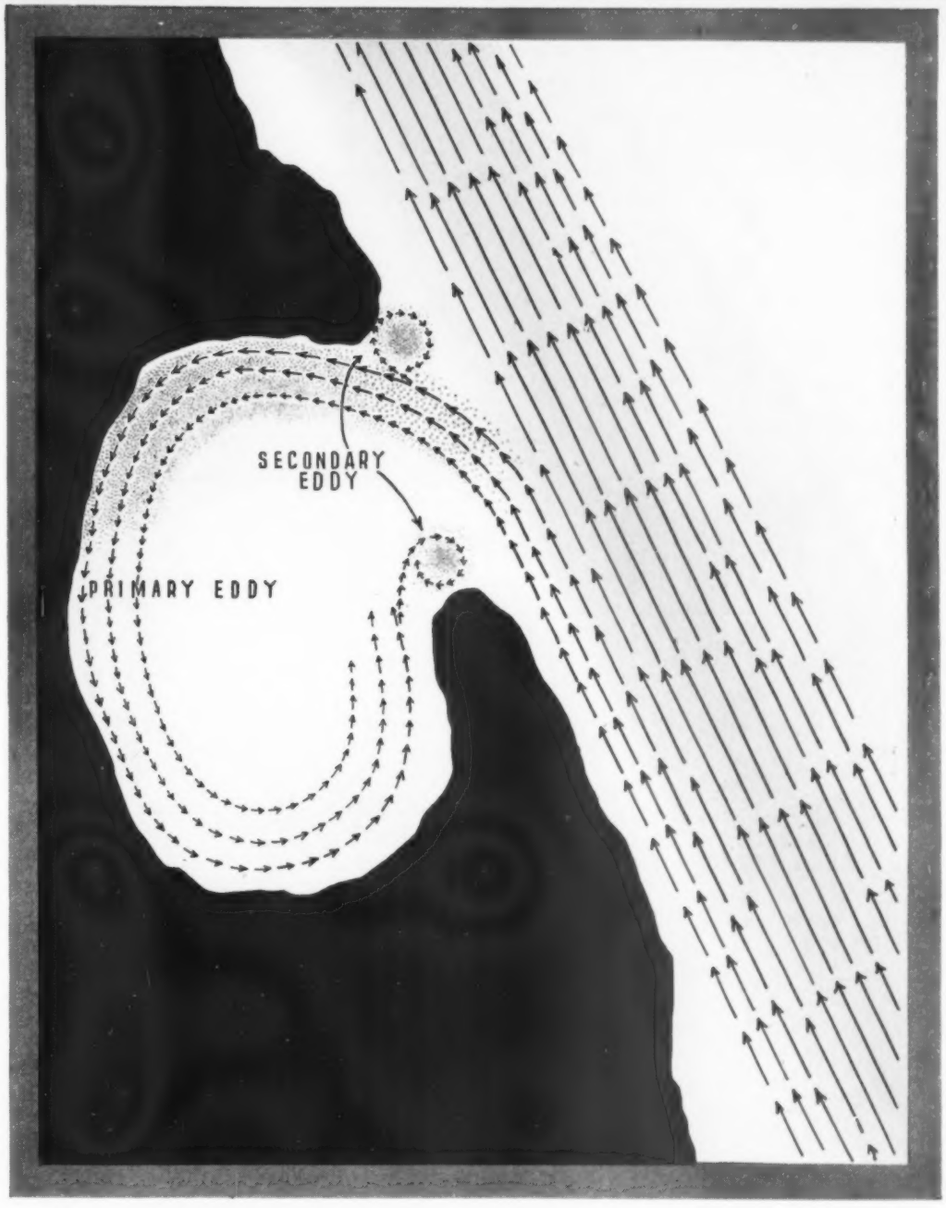
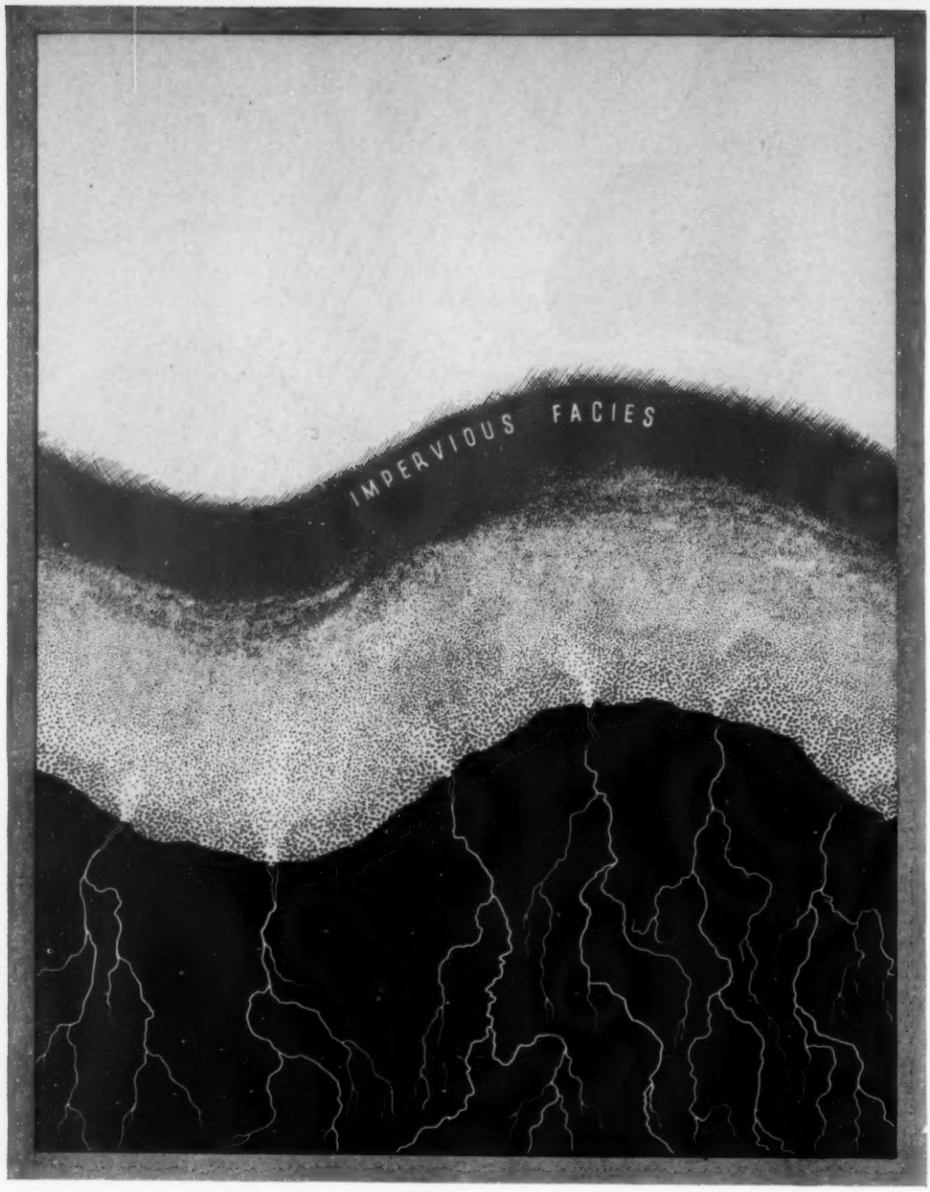


Diagram to illustrate the location and contours of depositional units controlled by eddy currents. The eddys are initiated when a littoral current sweeps by a projecting headland. The spacing of the arrows indicates the relative velocities of various portions of the currents; the middle portion of the littoral current moves most rapidly, the seaward portion is somewhat retarded by friction with relatively quiescent ocean water; the landward portion receives maximum retardation because of friction generated against land, the shallowing seafloor, and the back-moving water of the eddy. Deposition of coarsest sediments develops a linear arrangement, an arcuate contour being imparted by the course of the eddy current.

Field methods are crucial phases of any exploratory program and may be considered to be a more direct, though not necessarily a more reliable means of accumulating data than the devious routine of collecting, analysis, and interpretation by separate agencies. Moreover, the field techniques now in use, with special reference to geophysical types, may prove a most effective method of disclosing the concealed presence of sedimentary conditions which are favorable for oil accumulation. As has been noted with regard to other principles, progress in geophysical prospecting is more likely to come from further evolution of existing methods than from revolutionary new developments. Hence, seismograph surveys, both reflection and refraction types, must certainly continue to be an important source of subsurface data. Heretofore it appears that the primary use of the seismograph has been for the detection of domal and anticlinical arches, and more casually for tracing the configurations of key horizons throughout considerable areas. In the future it seems possible that techniques based on the same principles may be perfected to make even more appropriate studies. Since seismograph measurements depend upon the velocity of vibratory waves in strata of different densities and elasticities, and since density and elasticity are functions of porosity, it seems reasonable to expect that the method might somehow be modified to yield significant data regarding porosity variations. Although the application of electrical transmission methods is at present largely confined to the practice of well-logging, it is possible that field methods based on the same principles may be profitably revived. Resistivity and self-potential measurements are distinctly related to the permeability and porosity of formations and must therefore be adaptable to the purpose of discovering occurrences of impervious zone developed within stratal limits. Should such data be procurable through the agency of electrical transmission, it is suggested that surface surveys be augmented with similar porosity-permeability studies of the well-section.

To speculate a bit further upon the possible applications of both seismic and electrical methods to prospecting for sedimentary traps, it is conceivable that observations based on these principles may prove feasible from well-bore to outcrop and between well-bores. Procedures of



Conceptual diagram illustrating the manner in which rivers, emerging from an arcuate coastline, lend impetus to the momentum which carries their loads seaward. The directions of impetus are determined by the positions of debouchure upon concave or convex arcs. There may be a tendency for the arcuate contour of the coastline to be transmitted into the internal textures of the off-shore deposits. Ideal distribution of sediments by waves in near-shore areas is characterized by a gradation of coarse to fine particles seaward. (Along-shore currents may interfere and alter the direction of gradation to an angle other than normal to the coastline.) It is supposed that the arcuate contour may some place coincide with the development of impervious facies seaward thus providing a closed sedimentary structure suitable for petroleum accumulation.

this sort involve the transmission of shock or electrical impulses from a point on the surface exposure of a formation considered to be potential path of migration for petroleum. Instruments designed to receive the impulses are placed opposite the same formation in wells which are present within the effective range of the particular impulse to be transmitted and recorded. The same survey may be operated between transmitting and receiving instruments which are both suspended in well-bores opposite the single bed or formation. The location of the porosity anomalies so indicated might be further ascertained by the use of some such devices as sonic emanators and sonometers which depend upon the reflection of sound waves, above or below the audible range, to determine a constant distance from the variables of time and density. It is exceedingly probable that the latter proposals have no verification in past practice, and the question of their practicability is another problem for trained geophysicists.

Rather than an end to field geology, it seems more likely that the future holds the promise of even greater opportunity than the past has known. Prospecting must be conducted under more exact scientific principles and the foundation for their practice must be built with a care for detail and accuracy that has heretofore been rejected as uneconomical. The industry to an encouraging extent has recognized the desirability of reducing unwholesome features in competition which call for speed at the expense of accuracy. The steps taken toward cooperative development of fields have already accomplished a substantial improvement by directing the production of wells in a deliberate manner compatible with the best interests of all operators. That such an enlightened policy can prevail within modern industry is indicative of a receptive atmosphere for similar innovations in the phase of exploration. The prime significance of the speculations here set down does not rest with the mere expression of thoughts, but rather in the ability and essential need of scientific industrial enterprise to preclude deliberate action with considered hypotheses.

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World Production For 1941 Up 4.68 Percent

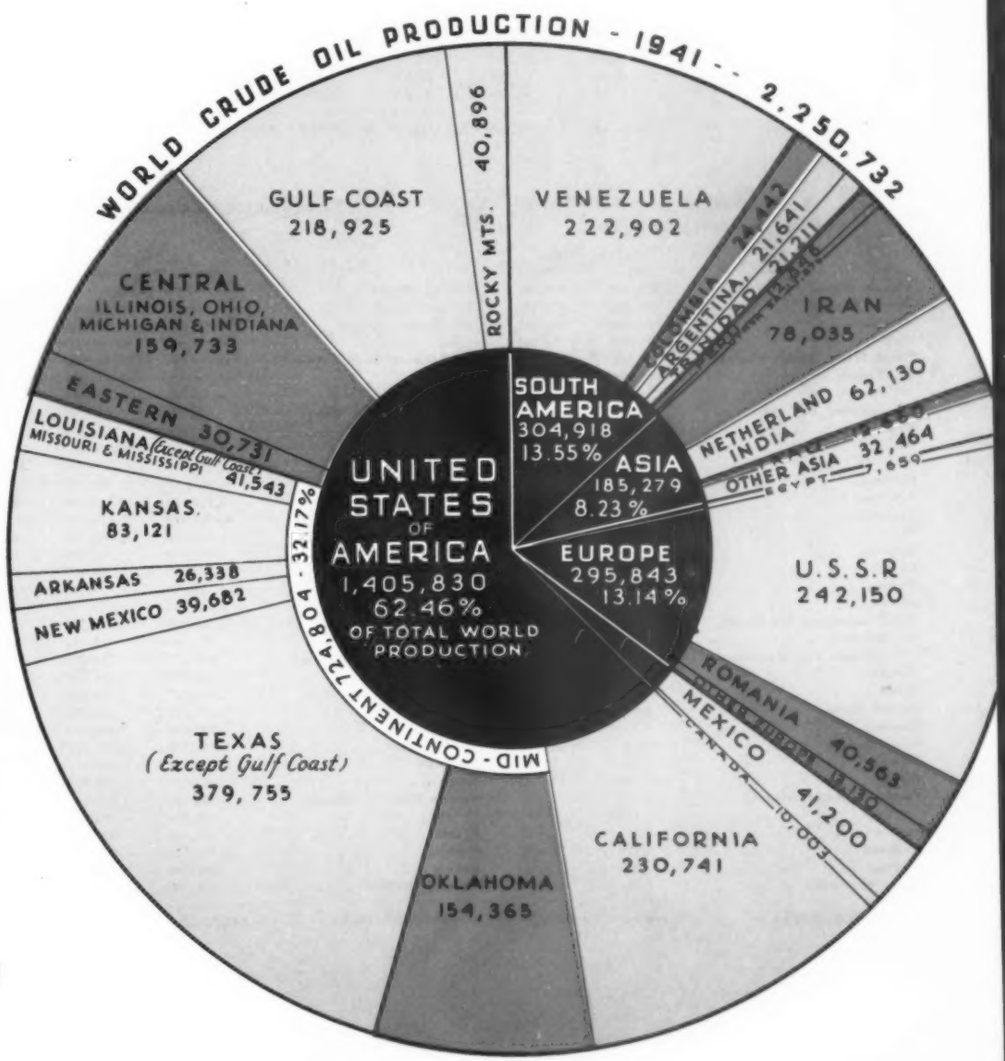
DUE TO THE statistical blackout covering all the oil producing countries outside the United States and South America, the annual world crude oil production figures compiled by WORLD PETROLEUM for the past twelve years were prepared this year under difficult conditions. Figures for Europe and Asia are largely estimates as no official data are available from these areas. They are estimates, however, based on the most careful study of all known events affecting petroleum production, on every scrap of information coming from these countries in regard to individual fields, percentages of plan fulfillment, and availability of drilling equipment. This information, correlated with records of fields and countries maintained for many years before the war, justifies the publication of these figures as close estimates if not absolutely accurate figures.

U. S. figures, covering 62.46 percent of world production, are of course, still officially available, although the final Bureau of Mines figure for the year has not been released at time of publication. These figures indicate that U. S. crude production as a whole increased by 52,618,000 bbl. or 3.89 percent over 1940. Oklahoma and the Eastern area showed slight decreases; Illinois showed a substantial decrease during 1941, having dropped 9.00 percent compared with 1940. This was more than offset by an increase in Gulf Coast production amounting to 8.73 percent. Substantial gains in production were recorded in Texas, Kansas, and Louisiana.

South America as a whole showed the most impressive increase in production which was 38,092,000 bbl. higher in 1941 than in 1940. This increase of 14.28 percent is entirely accounted for by Venezuela which, after an unsatisfactory year's production in 1940, improved crude output by 20.64 percent, or 38,141,000 bbl. almost exactly equal to the entire South American increase. Drilling in Colombia for the past few years has yielded disappointing results leading to a decrease in production for 1941 of 1,141,000 bbl. or 4.50 percent compared with 1940. Since both the Petrolea field on the Barco Concession and the Infantas-La Cira field on the De Mares Concession are entirely drilled up and only one new discovery recorded in the central Magdalena Valley during the past year, it may be assumed that this decreasing trend will continue during the coming year. Trinidad (official figures for which are not available) and Argentina showed slight increases in 1941 while Peru's production declined slightly. Altogether South America is the second largest major producing area of the world, accounting for 13.55 percent of world production during 1941. Since Russia is included with Europe for the purposes of these statistics, Europe becomes the third largest producing area in the world, supplying 13.14 percent of world crude oil production. It will be noted, however, that Russia alone increased production in 1941, while Rumania and Other Europe showed decreased production. The figures for the Soviet Union are based on estimates made by Basil B. Zavoico for a paper that will be delivered at the February meeting of the American Institute of Mining and Metallurgical Engineers. The utmost care has been used in checking and verifying as far as possible this estimate, the more so as an increase of 8.78 percent in Russian production was hardly anticipated while that country was actively engaged in war on a gigantic scale. Nevertheless, an increase of close to 19,550,000 bbl. seems definitely to be indicated. Rumania, on the other hand showed a decrease of 4.61 percent in production. It should be noted, however, that the rate of production was improving in Rumania toward the close of the year and it is to be expected that output will show an increase during the coming year if the fields are undisturbed by the incidence of war. In considering the monthly figures allowance should be made for seasonal variation due to reduced rate of transportation on the Danube in winter when parts of the river are frozen.

The statistical blackout is most complete in Asia including the Middle East and Far East. A decrease of 5.72 percent for this area is estimated due mainly to disturbed conditions in Iraq. It will be seen that Iraq production declined by the startling figure of 11,575,000 bbl. or 47.78 percent in 1941 against 1940. This was due to the closing of one half of the pipe line before the Allied occupation of Syria and the virtual cessation of production during the Iraq revolt. Production in Iran, Netherlands India and elsewhere in the Far East may be assumed to have remained about equal to the previous year's figure. Production of 41,200,000 bbl. for Mexico is assumed on the basis of an official Pemex announcement although estimates from well informed private sources indicate production of less than 37,000,000 bbl. Canadian production showed an increase of 14.74 percent, or 1,285,000 bbl. for 1941 compared with 1940.

World crude oil production chart: all figures in thousands of barrels (000 omitted); orange areas indicate decrease in production from 1940; blue areas indicate increase. Due to suspension of official statistics during the war figures from Europe and Asia should be treated as estimates subject to later revision.



Figures in U. S. barrels of 42 gal.

U. S. BARRELS

	Jan. 1941	Feb. 1941	March 1941	April 1941	May 1941	June 1941	July 1941	August 1941	Sept. 1941	Oct. 1941	Nov. 1941	Preliminary Figures Dec. 1941
United States	110,647,000	100,791,000	112,317,000	111,080,000	116,976,000	115,027,000	118,251,000	121,354,000	119,446,000	126,145,000	124,548,000	128,748,000
Soviet Union	19,014,000	18,410,000	20,977,000	21,813,000	24,108,000	22,572,000	19,989,000	19,401,000	18,395,000	19,400,000	18,773,000	19,398,000
Venezuela	15,249,057	14,931,677	16,096,650	16,904,850	18,588,600	18,939,400	19,057,895	19,666,200	18,737,450	21,181,575	21,417,300	22,131,210
Iran	6,560,000	6,127,200	6,560,000	6,500,000	6,596,084	6,500,000	6,596,084	6,596,084	6,424,140	6,596,084	6,383,280	6,596,056
Netherlands India: Sumatra	3,345,000	3,300,000	3,350,000	3,300,000	3,400,000	3,400,000	3,500,000	3,500,000	3,345,060	3,500,000	3,387,090	3,499,900
Borneo	1,070,400	1,000,000	1,100,000	1,000,000	1,200,000	1,200,000	1,240,000	1,240,000	1,117,320	1,240,000	1,200,000	1,240,000
Java	537,600	500,000	550,000	500,000	575,000	575,000	594,000	594,000	546,360	594,000	574,830	593,991
Molucca and Other	60,300	58,000	60,500	5,500	60,000	60,000	62,000	62,000	58,980	62,000	60,000	62,000
Rumania	1,961,108	2,982,848	3,294,051	3,272,177	3,253,762	3,186,937	4,041,875	3,723,112	3,796,875	3,796,875	3,580,095	3,672,785
Mexico	3,985,000	3,232,000	3,515,000	3,403,000	3,515,000	3,417,000	3,516,000	3,360,000	3,252,000	3,361,000	3,253,000	3,391,000
Iraq	1,000,000	950,000	900,000	800,000	200,000	250,000	800,000	1,000,000	1,250,000	1,500,000	2,000,000	2,000,000
Colombia	1,900,000	1,637,000	1,902,000	1,658,000	2,290,000	2,078,000	2,118,981	2,306,595	2,051,610	2,211,545	2,108,783	2,179,052
Trinidad	1,800,000	1,700,000	1,750,000	1,725,000	1,800,000	1,750,000	1,800,000	1,800,000	1,743,840	1,800,000	1,741,920	1,799,884
Argentina	1,827,660	1,682,103	1,808,300	1,772,670	1,831,759	1,800,000	1,840,000	1,840,000	1,778,100	1,840,000	1,780,620	1,839,974
Peru	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,110,000	1,147,000	1,147,000	1,037,520	1,147,000	1,110,000	1,147,000
Bahrein	628,000	562,000	635,000	561,000	635,000	608,000	635,000	635,000	528,000	478,000	462,570	477,989
Burma	648,551	585,800	648,551	650,000	655,220	650,000	660,000	660,000	645,450	660,000	638,700	659,990
Canada	802,652	737,313	849,706	822,164	843,134	818,000	876,845	870,881	878,782	843,820	816,390	843,603
Brunei	472,024	449,763	472,024	464,751	464,751	460,000	465,000	465,000	458,430	465,000	450,000	465,000
Great Germany: Old Reich	380,000	350,000	380,000	377,622	375,000	370,000	370,000	370,000	366,990	370,000	358,050	369,985
Ostmark	58,000	58,000	58,800	58,359	58,000	55,000	58,000	58,000	57,150	58,000	56,130	58,001
Slovakia and Moravia	9,800	9,000	9,800	9,800	9,000	8,000	9,000	9,000	9,030	9,000	8,700	8,990
Poland	320,700	300,000	320,700	320,000	300,000	300,000	310,000	232,500	225,000	232,500	225,000	232,500
Japan	218,000	218,000	218,000	218,000	220,000	220,000	227,300	227,300	218,100	227,300	219,960	227,292
British India	185,344	185,344	185,344	185,344	188,240	188,240	194,515	194,515	186,030	194,000	188,240	194,494
Ecuador	105,201	109,502	110,061	116,094	162,161	162,622	127,365	110,934	111,009	108,899	140,447	196,703
Saudi Arabia	467,900	467,900	467,900	470,000	470,000	470,000	520,000	520,000	475,740	520,000	502,260	519,002
Sarawak	108,000	108,000	108,000	108,000	108,000	108,000	112,000	112,000	107,640	112,000	108,390	112,003
Egypt	650,000	600,000	650,000	625,000	650,000	625,000	650,000	650,000	629,640	650,000	629,010	647,977
Italian Empire: Albania	125,000	115,000	120,000	115,000	115,000	110,000	115,000	115,000	110,000	115,000	111,270	114,979
Italy	4,000	3,900	4,000	3,864	3,800	3,800	3,800	3,800	3,810	3,800	3,600	3,720
France	40,000	35,000	40,000	39,922	40,000	40,000	41,000	41,000	40,000	41,000	39,660	40,982
Hungary	175,000	180,000	185,000	195,000	200,000	210,000	217,000	217,000	220,000	227,300	219,960	227,292
Bolivia	10,802	9,500	10,002	10,802	10,000	10,000	10,000	10,000	10,000	10,000	9,660	9,982
Other Countries	47,800	47,800	47,800	47,800	48,000	48,000	49,500	49,500	47,670	49,500	47,910	49,507
WORLD TOTAL	175,414,699	163,433,650	181,101,189	180,182,219	190,949,511	187,329,999	190,205,160	193,141,421	188,308,726	199,750,198	197,153,825	203,760,843

Daily Averages in Barrels

	Jan.—Dec. 1941	1940
United States	3,851,589	2,697,306
Soviet Union	663,424	608,196
Venezuela	610,690	504,812
Iran	213,794	216,261
Netherlands India: Sumatra	111,855	110,893
Borneo	37,939	35,485
Java	18,451	17,799
Molucca and Other	1,974	1,999
Rumania	111,130	116,188
Mexico	112,876	110,149
Iraq	34,657	66,188
Colombia	66,963	69,925
Trinidad	58,111	55,242
Argentina	59,291	56,330
Peru	35,193	35,478
Bahrein	18,755	19,386
Burma	21,266	21,122
Canada	27,406	23,819
Brunei	15,210	15,654
Great Germany: Old Reich	12,158	12,415
Ostmark	1,896	1,963
Slovakia and Moravia	299	324
Poland	9,093	10,632
Japan	7,285	7,209
British India	6,218	6,147
Ecuador	4,276	6,418
Saudi Arabia	16,084	14,657
Sarawak	3,594	3,598
Egypt	20,982	16,539
Italian Empire: Albania	3,784	4,090
Italy	125	156
France	1,311	1,356
Hungary	6,776	4,795
Bolivia	330	301
Other Countries	1,591	1,584
WORLD TOTAL	6,166,376	4,874,416

Official Crude Oil Production Figures for 1935 to 1941 (Preliminary) in Barrels

	1941	1940	1939	1938	1937	1936	1935
United States	1,405,830,000	1,353,214,000	1,264,962,000	1,214,355,000	1,279,160,000	1,098,516,000	996,596,000
Soviet Union	242,150,000	222,600,000	216,727,024	206,192,000	201,856,661	199,635,921	184,008,033
Venezuela	222,901,864	184,761,241	205,783,650	188,429,050	187,675,477	155,270,840	148,809,057
Iran	78,035,012	79,151,675	78,151,332	78,320,840	78,109,001	62,977,950	57,520,488
Netherlands India: Sumatra	40,827,050	40,586,986	41,557,013	34,538,128	33,451,511	30,469,428	28,004,595
Borneo	13,847,720	12,987,599	13,125,425	12,812,383	12,960,072	13,068,910	13,529,185
Java	6,734,781	6,514,462	6,568,714	6,955,283	7,152,931	3,618,293	3,462,440
Molucca and Other	720,780	731,746	836,144	607,622	537,436	375,823	311,872
Rumania	40,562,500	42,524,988	45,931,846	48,366,000	52,395,725	63,532,846	61,270,072
Mexico	41,200,000	40,314,787	39,428,141	38,505,824	46,455,687	41,027,915	40,240,563
Iraq	12,650,000	24,225,007	30,791,132	32,404,000	30,603,660	29,913,150	27,410,983
Colombia	24,441,566	25,592,890	22,036,613	21,581,588	20,297,543	18,756,110	17,597,655
Trinidad	21,210,644	20,218,566	19,270,256	17,736,176	15,502,989	13,237,030	11,671,224
Argentina	21,641,186	20,616,928	18,738,003	17,076,237	16,354,717	15,457,960	14,297,025
Peru	12,845,520	13,985,284	13,587,906	15,908,279	17,459,112	17,593,069	17,056,555
Bahrein	6,845,559	7,095,370	7,588,554	8,297,998	7,762,264	4,644,635	1,264,807
Burma	7,762,262	7,730,901	7,872,981	7,499,498	7,847,553	7,587,718	7,181,113
Canada	10,003,290	8,718,053	7,837,503	6,965,457	2,996,633	1,507,931	1,447,204
Brunei	5,551,743	5,729,374	5,767,227	5,387,214	4,397,038	3,296,938	3,302,905
Great Germany: Old Reich	4,437,647	4,543,955	4,487,491	3,850,044	3,148,300	3,076,858	2,967,438
Ostmark	692,240	718,494	693,247	370,038	221,266	50,092	44,347
Slovakia and Moravia	109,120	118,775	119,380	132,005	123,474	126,603	136,580
Poland	3,318,900	3,891,456	3,898,044	3,828,438	3,799,862	3,869,575	3,901,881
Japan	2,659,252	2,638,644	2,652,930	2,511,184	2,487,841	2,403,072	2,294,878
British India	2,269,650	2,249,835	2,332,467	2,330,209	2,161,653	1,978,329	2,037,810
Ecuador	1,560,998	2,349,015	2,312,118	2,257,278	2,161,436	1,942,467	1,731,785
Saudi Arabia	5,870,702	5,364,610	3,933,904	495,138	64,968	19,777	Nil
Sarawak	1,312,033	1,317,185	1,329,645	1,624,882	1,655,565	1,547,882	1,776,593
Egypt	7,658,627	6,053,367	4,603,797	1,561,231	1,163,267	1,262,666	1,255,151
Italian Empire: Albania	1,381,249	1,497,124	1,393,727	437,597	380,292	219,693	41,218
Italy	45,894	57,350	91,330	106,083	112,700	129,653	128,615
France	478,564	496,420	500,815	516,240	507,067	534,063	529,664
Hungary	2,473,552	1,755,000	815,248	330,829	13,910	100	Nil
Bolivia	120,748	110,484	100,885	106,620	123,123	104,746	163,295
Other Countries	580,787	580,001	578,036	243,000	70,000	37,100	32,300
WORLD TOTAL	2,250,731,440	2,150,041,572	2,076,404,528	1,982,639,390	2,041,170,134	1,797,791,150	1,652,023,331

PRODUCTION

—Conversion ratios are weighted averages for individual countries

METRIC TONS

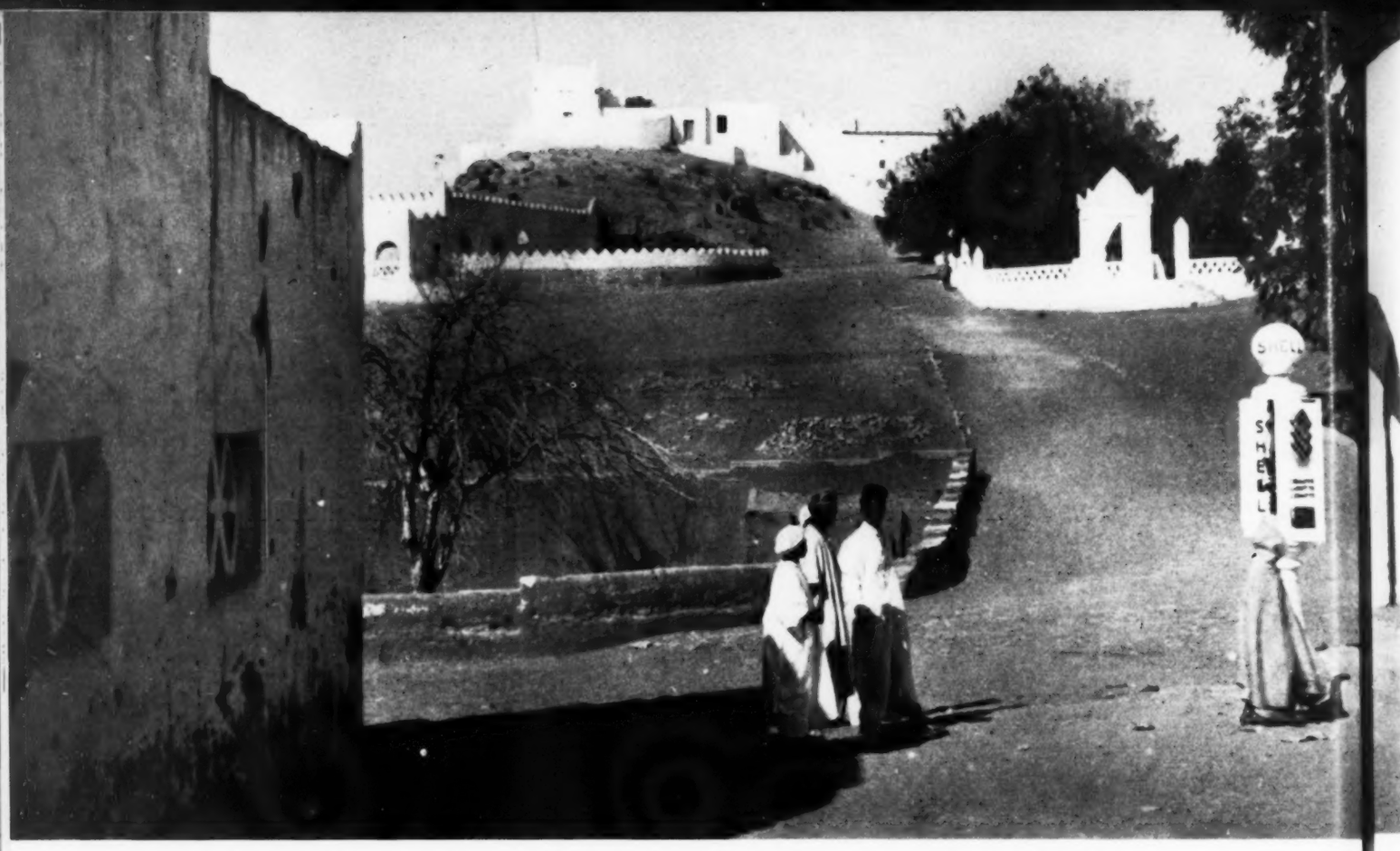
	Jan. 1941	Feb. 1941	March 1941	April 1941	May 1941	June 1941	July 1941	August 1941	Sept. 1941	Oct. 1941	Nov. 1941	Preliminary Figures Dec. 1941
United States	14,971,000	13,637,000	15,433,000	15,029,000	15,827,000	16,563,000	15,999,000	16,419,000	16,161,000	17,067,000	16,851,000	17,420,000
Soviet Union	2,609,000	2,525,000	2,870,000	3,006,000	3,307,000	3,096,000	2,742,000	2,661,000	2,523,000	2,661,000	2,575,000	2,661,000
Venezuela	2,264,151	2,217,027	2,390,000	2,510,000	2,760,000	2,812,086	2,829,977	2,920,000	2,782,100	3,145,000	3,180,000	3,286,000
Iran	870,257	812,842	870,257	862,298	875,044	862,298	875,044	875,044	852,234	875,044	846,813	875,041
Netherlands India: Sumatra	428,242	422,481	428,888	422,481	435,284	435,284	448,086	448,086	428,250	448,086	433,630	448,073
Borneo	137,038	128,025	140,827	128,025	153,629	153,629	158,750	158,750	143,044	158,750	153,629	158,750
Java	68,826	64,012	70,414	64,012	73,614	73,614	76,047	76,047	69,948	76,047	73,592	76,045
Molucca and Other	7,720	7,425	7,745	7,041	7,681	7,681	7,938	7,938	7,551	7,938	7,681	7,938
Rumania	265,913	404,454	446,651	443,685	441,188	432,127	548,051	504,828	514,830	514,830	485,437	498,005
Mexico	585,169	474,596	516,153	499,706	516,153	501,762	516,300	493,392	477,533	493,539	477,680	497,944
Iraq	133,672	126,989	120,305	106,938	26,784	33,418	106,938	133,672	159,418	200,508	267,344	267,344
Colombia	264,993	228,312	265,272	231,241	319,386	289,819	295,534	321,700	286,138	308,434	294,112	303,912
Trinidad	253,165	239,100	246,132	242,616	253,165	246,132	253,165	153,165	245,266	253,165	244,996	253,148
Argentina	260,350	239,616	257,593	252,517	260,984	256,410	262,108	262,108	253,291	262,108	253,650	262,105
Peru	132,013	132,013	132,013	132,013	132,013	146,535	151,419	151,419	136,966	151,419	146,535	151,419
Bahrein	85,699	76,692	86,654	76,556	86,654	82,969	86,654	86,654	72,052	65,229	63,124	65,228
Burma	89,579	80,912	89,579	89,779	90,500	89,779	91,160	91,160	89,150	91,160	88,218	88,396
Canada	102,144	93,830	108,133	104,628	107,296	104,098	111,586	110,827	111,833	107,384	103,893	107,356
Brunei	61,978	59,055	61,978	61,023	61,023	60,399	61,056	61,056	60,193	61,056	59,086	61,056
Great Germany: Old Reich	54,340	50,050	54,340	54,000	53,625	52,910	52,910	52,910	52,480	52,910	51,201	52,908
Ostmark	8,766	8,646	8,766	8,700	8,646	8,199	8,646	8,646	8,520	8,646	8,368	8,646
Slovakia and Moravia	1,444	1,326	1,444	1,444	1,326	1,179	1,326	1,326	1,330	1,326	1,282	1,325
Poland	43,227	40,437	43,227	43,132	40,437	40,437	41,785	31,338	30,328	31,338	30,328	31,338
Japan	31,010	31,010	31,010	31,010	31,294	31,294	32,333	32,333	31,024	32,333	31,289	32,332
British India	25,600	25,600	25,600	25,600	26,000	26,000	26,867	26,867	25,695	26,795	26,000	26,864
Ecuador	13,870	14,437	14,510	15,306	21,379	21,440	16,792	14,625	14,635	14,357	18,516	25,933
Saudi Arabia	63,851	63,851	63,851	64,138	64,138	64,138	70,961	70,961	64,920	70,961	68,540	70,825
Sarawak	13,816	13,816	13,816	13,816	13,816	13,816	14,328	14,328	13,770	14,328	13,866	14,328
Egypt	92,830	85,690	92,830	89,260	92,830	89,260	92,830	92,830	89,923	92,830	89,833	92,827
Italian Empire: Albania	18,735	17,236	17,986	17,236	17,236	16,487	17,236	17,236	16,487	17,236	16,677	17,233
Italy	497	484	497	480	472	472	472	472	472	472	447	462
France	5,610	4,909	5,610	5,600	5,610	5,610	5,751	5,751	5,610	5,751	5,563	5,749
Hungary	23,512	24,216	24,889	26,234	26,907	28,252	29,194	29,194	29,598	30,580	29,592	30,586
Bolivia	1,400	1,231	1,296	1,400	1,296	1,296	1,296	1,296	1,296	1,296	1,252	1,294
Other Countries	6,829	6,829	6,829	6,829	6,857	6,857	7,071	7,071	6,810	7,071	6,844	7,071
WORLD TOTAL	23,996,246	22,359,148	24,956,089	24,673,744	26,146,167	26,654,687	26,640,611	26,443,030	25,766,695	27,355,927	27,005,018	27,908,475

Daily Averages in Metric Tons

	Jan.—Dec. 1941	1940
United States	537,576	499,739
Soviet Union	91,079	93,443
Venezuela	90,675	74,954
Iran	28,362	28,534
Netherlands India: Sumatra	14,320	14,132
Borneo	4,857	4,543
Java	2,362	2,287
Molucca and Other	253	256
Rumania	15,068	15,754
Mexico	16,575	15,966
Iraq	4,612	8,849
Colombia	9,339	9,753
Trinidad	8,173	7,768
Argentina	8,446	8,024
Peru	4,646	4,689
Bahrein	2,559	2,646
Burma	2,930	2,918
Canada	3,488	3,031
Brunei	1,997	2,087
Great Germany: Old Reich	1,739	1,786
Ostmark	283	312
Slovakia and Moravia	44	49
Poland	1,226	1,423
Japan	1,036	1,029
British India	859	849
Ecuador	564	846
Saudi Arabia	2,195	1,986
Sarawak	460	460
Egypt	2,997	2,362
Italian Empire: Albania	567	613
Italy	16	19
France	184	190
Hungary	912	645
Bolivia	43	39
Other Countries	227	227
WORLD TOTAL	847,413	812,208

Official Crude Oil Production Figures for 1935 to 1941 (Preliminary) in Metric Tons

	1941	1940	1939	1938	1937	1936	1935
United States	191,377,000	182,904,479	171,152,192	164,346,325	172,822,797	148,707,864	134,912,143
Soviet Union	33,244,000	34,200,000	29,530,168	28,859,000	27,867,025	27,384,900	25,241,100
Venezuela	33,096,341	27,432,998	30,533,706	27,845,286	27,733,926	22,945,299	21,990,373
Iran	10,352,216	10,443,546	10,367,117	10,358,495	10,330,480	8,329,289	7,670,500
Netherlands India: Sumatra	5,226,865	5,172,209	5,320,320	4,662,836	4,490,137	4,114,710	3,759,006
Borneo	1,772,846	1,662,718	1,680,377	1,719,783	1,739,607	1,773,545	1,815,998
Java	862,218	836,982	842,237	933,595	960,125	499,097	464,757
Molucca and Other	92,277	93,569	107,047	81,560	72,139	50,446	41,862
Rumania	5,499,999	5,766,099	6,228,047	6,603,000	7,153,000	8,704,000	8,394,000
Mexico	6,049,927	5,843,395	5,794,035	5,716,423	6,896,657	6,090,842	5,973,955
Iraq	1,683,279	3,228,878	4,115,845	4,345,000	4,126,185	4,079,066	3,724,231
Colombia	3,408,853	3,569,434	3,067,568	3,007,935	2,844,251	2,614,092	2,452,635
Trinidad	2,983,215	2,842,918	2,710,515	2,472,943	2,181,676	1,862,796	1,642,446
Argentina	3,082,790	2,936,880	2,657,232	2,432,857	2,330,063	2,202,304	2,036,903
Peru	1,695,777	1,716,195	1,798,557	9,099,885	2,313,691	2,331,454	2,260,903
Bahrein	934,165	968,502	1,045,391	1,130,734	1,058,557	635,555	173,072
Burma	1,069,372	1,067,895	1,087,424	1,039,960	1,083,391	1,047,593	991,456
Canada	1,273,008	1,109,440	997,487	879,921	378,478	190,495	182,820
Brunei	728,959	764,006	768,320	707,123	576,545	470,991	471,842
Great Germany: Old Reich	634,584	653,590	647,337	552,074	453,451	444,600	427,400
Ostmark	103,195	114,045	109,904	63,468	33,010	7,473	6,616
Slovakia and Moravia	16,078	17,836	18,103	19,282	18,036	18,665	19,946
Poland	447,352	520,984	522,874	504,678	501,301	510,630	614,760
Japan	378,272	376,657	379,161	356,328	341,040	341,976	326,580
British India	313,488	310,596	322,160	322,125	298,450	273,137	281,072
Ecuador	205,800	309,686	306,824	319,877	306,326	275,293	245,434
Saudi Arabia	801,135	726,785	536,366	66,683	8,070	2,447	Nil
Sarawak	167,844	168,475	171,322	200,126	217,085	221,126	253,799
Egypt	1,093,773	864,514	657,570	223,058	166,298	177,491	176,436
Italian Empire: Albania	207,021	224,199	208,279	65,313	56,760	32,760	6,152
Italy	5,699	7,110	11,346	13,178	14,000	16,106	15,977
France	67,124	69,578	70,478	72,106	71,008	74,788	74,172
Hungary	332,748	236,025	109,896	42,798	13,910	13	Nil
Bolivia	15,649	14,249	11,998	13,262	15,487	13,197	20,540
Other Countries	82,968	82,779	82,300	34,080	10,000	5,300	4,600
WORLD TOTAL	309,305,837	297,267,251	283,969,503	279,111,097	279,482,962	246,449,340	226,610,486



Marketing in Africa occupies the efforts of most of the major international companies and involves substantial investment: the map of the facing page shows latest figures for consumption by countries in red as well as principal petroleum features.

AFRICA

Without Important Production It Is A Big Potential Market

By Karol N. Gess

Raw Material Resources in Africa Occupy an Important Position in Europe's Plans for the Future: But Widespread Exploration Has Failed to Reveal Significant Reserves Except in Egypt and Morocco. Exploration, Production, Refining and Consumption Reviewed.

ANY REVIEW of the oil industry in Africa must to a very considerable part be devoted to potential oil resources rather than to actual industrial developments. The most notable exception in this respect is Egypt. Here, however, a second difficulty is raised. It is hardly ever possible to deal with any industry within any given geographically defined area and this is especially true in Africa, both in respect of the Egyptian oilfields and also the refinery in the Canary Islands, which latter will be dealt with at a later stage. Though Egypt is located on the African continent its oil industry is inherently connected with that of Asia Minor, i. e. as a part of the Middle East area, both from the point of view of control and marketing. Egypt is the only country situated in Africa producing an appreciable quantity of crude oil, but does not, from the point of view of production, enter into the picture of the African oil industry as much as it does that of the Near and Middle East.

The most important country from the point of view of production wholly part of a picture of the African oil economy, and by far the most important one from the point of view of consumption is the Union of South Africa. Here production of oil from torbanite reached about 10,500 tons in 1939. Against this figure, however, must be set an annual consumption of petroleum products of over 1,100,000 tons. To the above production of oil from torbanite must be added the output of motor spirit from coal tar, but this is still below the 2,000 ton per year mark. Although South Africa's geographical position is favorable for the import of petroleum products from both the Western and Eastern Hemispheres considerable attention has been given to the possibility of reducing these by increased home production. As far as natural mineral oil is concerned, seepages exist in the Karoo district, but any venture here would be highly speculative, especially as the sinking of test wells to a depth of about 6,000 ft. would be involved and it is not thought that oil in commercial quantities is present. As regards the second possibility, torbanite and shale resources, workable deposits of these are only known in the Ermelo district of the Transvaal, about 150 miles East of Johannesburg, from which district the whole of the present South African torbanite output is derived. The torbanite is mined and retorted

here and then transported by rail to the vicinity of Johannesburg, where a refinery is located. Other shale deposits are known to exist on the Natal-Transvaal border and some years ago a company was formed to exploit these, but the venture was abandoned. The Union is rich in coal resources, and, together with Southern Rhodesia produced over 17,000,000 tons in 1938, of which about 2,000,000 tons were exported, about one half of this quantity in the form of ships' bunkers. Therefore consideration has been given to various means of producing oil from coal, either by hydrogenation or by the Fischer-Troppsch process. Although the coal is on the whole suitable as a raw material for such processes, other difficulties have so far stood in the way of their application, mainly difficulties in the adequate supply of water. An important factor favoring synthetic oil plants in South Africa is the low pit-head price of coal, averaging just over $1.00 per short ton of 2,000 lbs. in 1939, this being only about 40 percent of the pit-head price in Great Britain. Natural gas resources are also available in the Union, production in 1937 being valued at $12,500.

Relatively near to the Union of South Africa is an island which has so far shown the most promise of yielding natural mineral oil resources in that part of Africa. This is the French island of Madagascar. Exploration with modern equipment was only begun comparatively recently, after previous prospecting had yielded negative results, and so far the following discoveries have been made. Bituminous shale deposits have been found in the Samboina area of the Mahalavona mountain range. The shale is at a depth of about 300 feet and has an oil content of from 6.7 to 7.65 percent and extraction of the oil by hydrogenation has been suggested. Total known deposits are estimated at 12,000,000 metric tons of shale, which would yield a total of 1,500,000 tons of oil. The annual output would thus be relatively small when compared to the oil products requirements of East Africa, the nearest outside market, but it could easily cover the demand of the island itself for some considerable period and leave a surplus for export. Test wells for mineral oil have been sunk at Andrafiavelo, on the West coast of Madagascar and oil has been found at a depth ranging from 300 to 600 ft. Two wells are producing and their present yield can be estimated at about 250-300 tons annually. There are, however, indications that an increased yield can be expected.

The next and last African region where actual commercial production is in progress at present is French North Africa. Production in Algeria has never been appreciable, amounting to only

1,822 tons in the peak year of 1925, but since then there has been a steady decline in output, reaching only 259 tons in 1938. This production comes from fields in the vicinity of Relizane, 78 miles East of Oran. Further prospecting was progressing in this area at the outbreak of war, as well as in the immediate neighborhood of Oran and in two other regions further inland. It may be added that the benzol production of Algeria amounted to about 5,000 tons in 1937. The most important oil producing area in North Africa is in the Gharb plain, near Petitjean, in French Morocco. Here production has increased from 110 metric tons in 1935 to 3,200 metric tons in 1938. A refinery began operation in Morocco in December 1939, probably either at Petitjean or at Port Lyautey on the Atlantic coast. No details concerning this plant are known, except that the gasoline output of the plant is 30 percent of the crude charge. Altogether over 500 men, mainly natives, are employed in the Moroccan oil industry. Prior to the building of the local refinery the crude oil was shipped from Port Lyautey to Le Havre, France, for refining in the plants in that area and it was at the time hoped to increase production sufficiently to allow shipments of 1,000 tons to be made every six weeks. Prospecting in Morocco is continuing in the Gharb plain and in two other regions. In Tunisia prospecting is being carried out by government body ("Syndicat d'Etudes et de Recherches Petrolieres en Tunisie") and one well at Djebel Kebir, near Bizerta, has yielded gas at a depth of about 3,000 ft. Other wells at Rhazouane have yielded traces of oil and prospecting on a small scale was being continued at the outbreak of war.

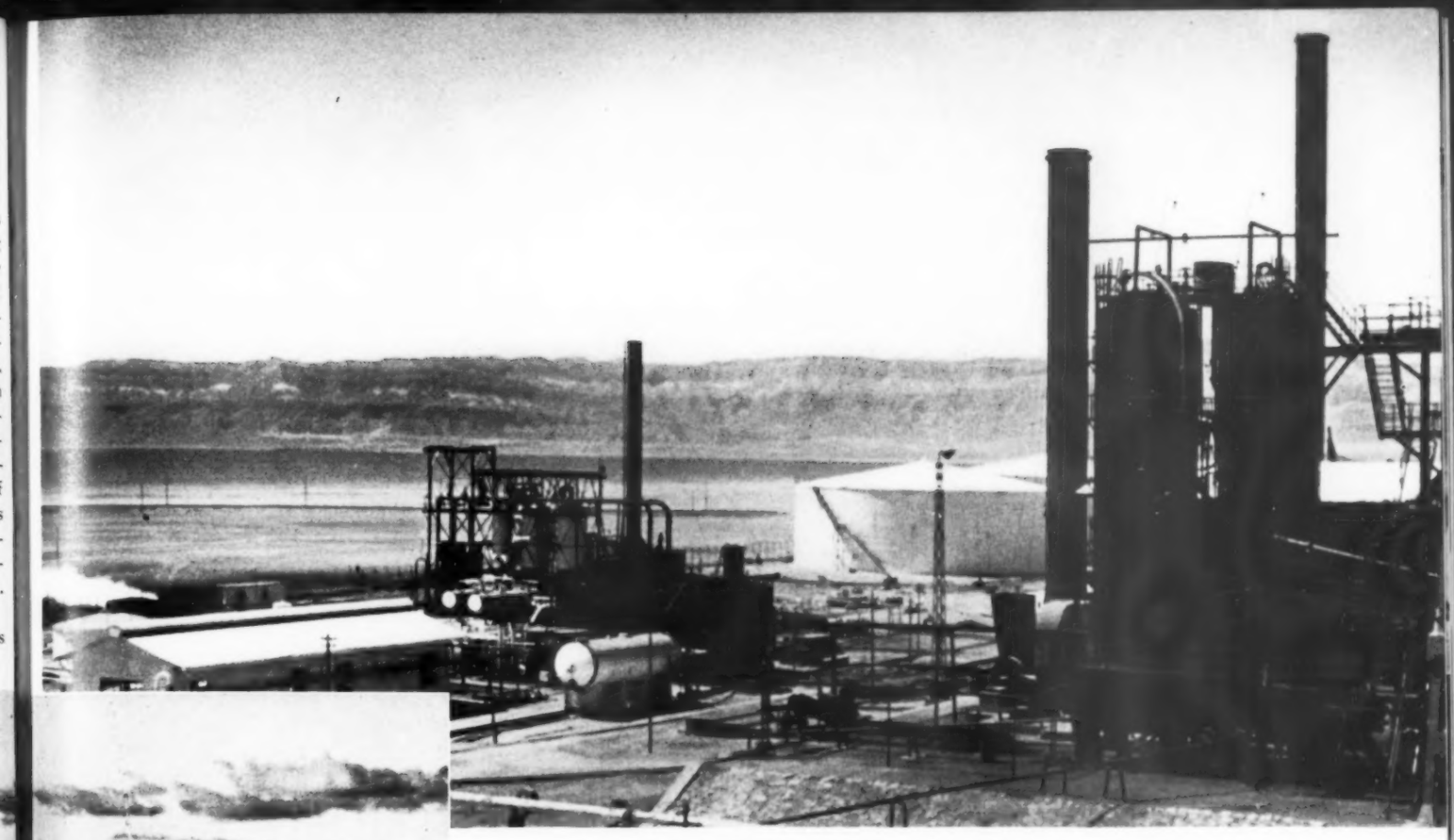
Turning to West Africa it will be found that exploration work is being pursued in practically all districts. The French colonies here appear to show most promise of actual oil resources being available. Many oil seepages have been found, as well as deposits of bituminous sands, notably in the Cameroon, near Douala and on the banks of the Cross River, and in French Equatorial Africa, where three wells have been sunk near Pointe Noire, but drilling was stopped at about 2,700 ft. owing to the inadequacy of the equipment. The question of equipment appears to have caused many difficulties in prospecting work in all French colonies and the work has been severely handicapped because of this. Only a few small rotary drilling outfits appear to have been available. Bituminous deposits have been found in the Gabon, on the Ogooue River and the material has already been used for road surfacing in the town of Libreville. Oil seepages also exist at the Tendo Lagoon and at the mouth of the River Tano in French West Africa, near the border of the Gold Coast Colony. Bituminous sands also found in this region have been used for road surfacing. So far seven test wells have been sunk near Abidjan and oil indications have been found at a depth of about 400 ft. Ten further test wells were sunk in the Gold Coast Colony and the distillation of bituminous deposits has also been attempted there. It may be mentioned that revenue in the Gold Coast from petroleum prospecting licenses granted in 1937 amounted to about $210. In Angola (Portuguese West Africa) oil has been found in the Dande and Cunga regions, but so far not in commercial quantities and prospecting activities in that area have been suspended. In Nigeria tests have been made at Awgu and in Southwest Africa at Berseba, but in the latter case the results have been negative and further tests have been suspended.

In East Africa exploration work has been undertaken in nearly all parts, but so far commercial exploitation has not begun in any area. In Abyssinia test wells have been drilled in the Harar, Dankalia (Aussa) and Ogaden districts. In Eritrea tests were made on the Buri peninsula and on Great Dahlac Island, off Northern-Eritrea. In British Somaliland oil seepages are known to exist near Berbera and some years ago exploration work was undertaken, but subsequently abandoned. It would, however, appear that this will be resumed again. Shortly before the outbreak of war an exploration license was granted for two large areas in Kenya, covering a very considerable part of the country. This fact had at the time aroused hopes that oil might also be found in the Eastern part of the Belgian Congo. In the Portuguese colony of Mozambique prospecting was undertaken some years ago and the work subsequently abandoned, but a new company was formed in 1939 before the outbreak of war to continue exploration.

It may be noted that in most areas where exploration and prospecting is now in progress such work had already been undertaken previously, usually with negative results. But in most cases such results cannot be accepted as final, owing to the inadequacy (by modern standards) of the equipment used and often also owing to the small scale on which the work was undertaken. Details of over 40 now liquidated companies provide an interesting record of such previous work. Apart from Egypt this was largely carried out in Algeria, Angola, the Gold Coast, Nigeria, Cameroon, British Somaliland, South and Southwest Africa, Nyasaland, Madagascar, Mozambique and Abyssinia. The total capitalization of the various companies engaged in this work was well in excess of $10,000,000. Most of the prospecting work was carried out in the period immediately preceding and following the last war.

The total consumption of petroleum products in Africa amounted to 4,400,000 tons in 1938, but the total refinery capacity available on that continent amounts to only 1,400,000 tons per year, when the definition "Africa" is used in its strict geographical sense. This qualification must be made as the above capacity figure includes a plant with a yearly capacity of 600,000 tons at Santa Cruz, Teneriffe, Canary Islands. This plant draws its crude supply both from the Western Hemisphere and from Iraq, supplying Spain, Portugal, Spanish Morocco and other Spanish colonies in West Africa with refined products. As the requirements of these African possessions

Sand dunes, pictured above, cover large areas of northern Africa making transportation and exploration extremely difficult.



One unit of Anglo-Egyptian's refinery in Egypt with the Suez canal in the background: the Egyptian production and refining capacity has proved of utmost importance in the present campaign in Libya 500 miles west of this plant.

amount to little over 12,000 tons yearly, the Santa Cruz plant should not be included in the African refinery capacity total. The total plant capacity is thus only about 832,000 tons per year, being distributed as follows: Two plants in Egypt with a total yearly capacity of 770,000 tons including cracking capacity of 115,000 tons; a plant at Johannesburg, South Africa with an annual charging capacity of 50,000 tons; the Leopoldville, Belgian Congo refinery with a capacity of 12,000 tons including a 7,500 ton cracking unit; and a refinery at Tripoli, Libya having a cracking capacity of 40,000 tons per year. There is also the new refinery in French Morocco, of unknown charging capacity.

The distribution of consumption by the different main refined products varies widely in different regions of Africa, the percentages being largely affected by fuel oil bunker exports. Thus the total consumption of the West Coast region was 1,300,000 tons in 1938, out of which total the bunker exports of the Cape Verde Islands and of French West Africa together accounted for 1,000,000 tons. To meet the heavy fuel oil requirements of the West Coast region a crude of the Venezuela type with its high fuel oil yield would appear most suitable, both from a technological and a transport point of view.

Apart from short pipelines in various port installations the main African pipelines are from Matadi to Stanley Pool in the Belgian Congo, over a distance of 217 miles, linking the Congo River estuary with the Leopoldville refinery; and a line from Ras Gharib to the Red Sea, in Upper Egypt, over some 30 miles. The former pipeline provides an interesting example of progressive development work in a country devoid of indigenous oil resources (as far as is known at present) and it may be noted that this pipeline was completed in 1913.

As far as present-day marketing organization is concerned, most of the major American and British oil companies market their products in most parts of Africa and the total investment in these organizations exceeds $25,000,000. Metropolitan French companies as well as American, British and some purely local companies operate in French Africa. It must be pointed out that these data apply to the period immediately preceding the outbreak of war. In East and South Africa the major Middle East producers (Shell, Anglo-Iranian and Caltex) maintain distributing facilities. Some Roumanian companies also had organizations in Egypt and in what was Italian East Africa until the beginning of last year, the A.G.I.P., an Italian government-controlled company, held a monopoly for the distribution of petroleum products. In Spanish Morocco and Spanish West Africa the market is supplied largely with products refined at the Santa Cruz, Teneriffe, plant of the Compania Espanola de Petroleos, S. A. (CEPSA).

Africa is rich in resources suitable for the production of vegetable oils of all kinds and in recent years considerable attention has been given to the possibility of producing Diesel oil and other liquid hydrocarbon fuels from these, especially in British East Africa. Technical committees to deal with this problem were set up in 1940. In Uganda Diesel oil is already being manufactured from cotton seed oil and the output of power alcohol, a by-product of sugar refining, amounted to 656 tons in 1939. Before the outbreak of war similar research work was contemplated in several French colonies in Africa. Further possibilities for the production of synthetic fuels may be found in the hydrogenation of African coal resources, mainly in the Union of South Africa and Southern Rhodesia.

EXTRACTION; NOT CONVERSION–

The Answer To Refiner's Mercaptan Problem

By M. J. Fowle & H. W. Field
The Atlantic Refining Company

Unisol Process Announced By Atlantic Removes Mercaptans From Gasoline Instead Of Converting Them To Disulfides

THE RECENT widespread publicity which has been given to the numerous and fascinating catalytic processes for the production of high octane gasoline has turned the attention of refinery supervisors and technologists away from many of their day-by-day headaches and has given them a respite from the grindstone which has been extremely refreshing. These new processes are being commercialized at an astounding rate, and new plants, urged by defense efforts, are springing up from coast to coast. This acceleration of technical progress is gratifying, and it should be a source of satisfaction to all refiners to realize that their research people can come through in the pinches and give them new methods which match, in all respects, the boldness and ingenuity which characterizes present day progress in other industries. It should be a further source of satisfaction for these refiners to realize that their research groups are keeping their feet on the ground and are apportioning their efforts in an attempt to strike a sensible balance between the work which may result in the development of radically new products and work aimed at the development of new processes to replace existing operations which are not entirely satisfactory. An excellent example of this balance of effort is given in the following discussion, which presents the research background and advance to commercialization of a process for removal of mercaptans from gasoline. This development is particularly interesting, since the deleterious effects of mercaptan conversion are well known, but only partial answers to the question of how to improve the situation have been available to the refiner, thus far.

These deleterious effects of mercaptan conversion upon octane number and susceptibility to octane improvement by the use of tetraethyl lead have been known for some years, and removal of mercaptans, rather than conversion, for improvement of odor was indicated. Many barriers, however, have blocked progress in this direction. The mercaptans in the high boiling fractions of gasoline are particularly troublesome, because they are not sufficiently soluble in a cheap reagent, such as caustic soda, to permit ready and simple extraction. Organic solvents, either alone or in caustic soda solution, tend to be excessively expensive, particularly if appreciable quantities are lost in the treated naphtha. Further, any solvent which removes mercaptans will, of necessity, gradually become fouled with sulfides, sulfates, thiosulfates, phenols, thiophenols, fatty acids, etc., unless some mechanism is provided for discharging these materials from the recirculation system without incurring excessive cost of reagent loss. These deterrents have resulted in a stalemate at the naphtha treating plant, which seemed to indicate that this phase of refinery activity was frozen and that mercaptan conversion, by doctor sweetening or otherwise, would continue to predominate as the method for improving gasoline odor. Gasoline, however, is a large-volume product of the refinery, and small savings per gallon expand to large annual returns—large enough to furnish the driving force for extensive research and development work. The Unisol process, which uses a solvent composed of aqueous caustic soda and methanol, has been developed by the Atlantic Refining Company to meet the requirements imposed by this mercaptan-removal problem. The results of extensive semi-commercial operation have demonstrated that all of the requirements previously mentioned have been satisfied, and large plant installations are being expedited.

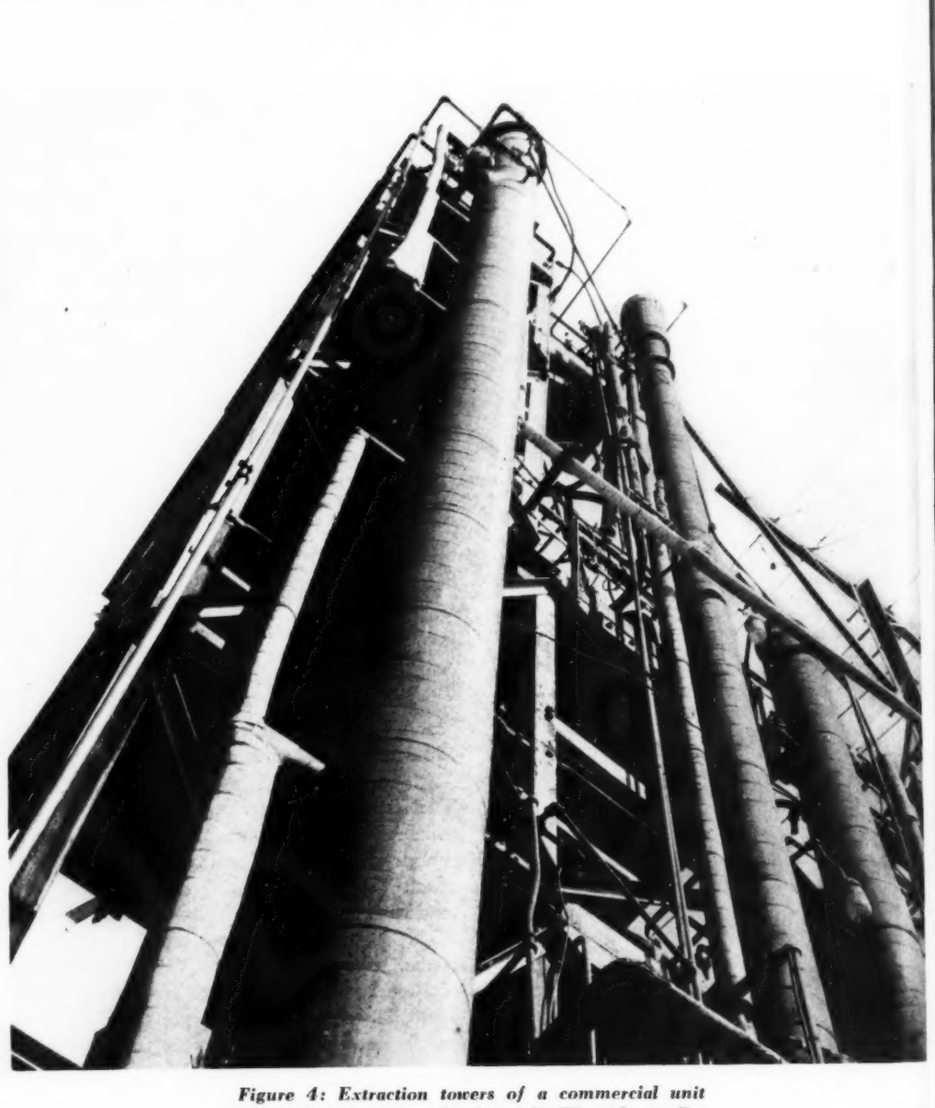


Figure 4: Extraction towers of a commercial unit of the Unisol process developed by The Atlantic Refining Company for the extraction of mercaptans from gasoline.

The caustic-methanol process was conceived some years ago, but was not commercialized at that time because of the lack of the large dollar driving force which has become apparent recently. The process, in developed form, has a research background of extensive studies of physical and chemical properties involving naphthas, mercaptans, solvents, and phenolic contaminants; alone, and in mixture with aqueous caustic soda of various concentrations. The end product of this investigation is the result of economic evaluation of such factors as low cost of solvent compounds, low loss in treated naphtha, high solubility for mercaptans resulting in low recirculation rates, ease of separation of solvent components to permit ready control of recycle contamination, and overall flexibility with regard to sources and types of naphthas which can be handled. Figure No. 1 is a plot of mercaptan content against contact stages for a typical cracked gasoline of moderate sulfur content. The efficacy of the combined caustic-methanol solvent over caustic soda treatment is demonstrated, and the mercaptan removal power of the solvent is emphasized by the relatively high extraction temperature used, 100 deg. F. Many more data of a similar nature were obtained, but the scope of this discussion does not permit inclusion here.

The nominal capacity of the semi-commercial plant was 50 bbl. per day, but, in operation, the rate was varied from 15 to 300 bbl. per day in the course of obtaining data for use in full scale design. A simplified flow diagram of the plant is given in Figure 2. Sour gasoline, essentially free of hydrogen sulfide, flows upward through a countercurrent extraction tower, packed with Raschig rings. Regenerated caustic soda solution is pumped to the top of the tower and flows down through the upper section, removing practically all of the methanol from the demercaptanized gasoline. In the lower section of the column, the methanol is introduced, and the combined solvents extract the mercaptans from the gasoline. The spent reagent from the bottom of the extraction tower is pumped to a steam stripping tower, and the regenerated caustic is withdrawn from the bottom of this tower. This solution is recycled to the top of the extraction tower. The overhead from the stripper—a mixture of methanol, mercaptans and steam—is condensed, and the condensate separates into two layers in the receiver. The mercaptans collect in the upper layer and are withdrawn from the system. The lower layer is a water-methanol mixture which is maintained low in mercaptan content by controlling the water-methanol ratio to give minimum mercaptan solubility. The water-methanol mixture is drawn from the bottom of the mercaptan separator and pumped to the methanol fractionator. The methanol taken overhead in the fractionator is recycled to the middle section of the extractor. The water residuum from the fractionator recycles to the caustic stripper. Figure 3 on page 46 gives a general idea of the size and scale of the semi-commercial plant under discussion, and Figure 4 on page 44 is a view of the extraction tower.

Table No. 1 presents the type of information obtained from the semi-commercial plant. The particular run presented is on a Gray-processed cracked gasoline. It is noteworthy that this gasoline has a full boiling range (422 deg. F. E. P.), and yet the high capacity of the caustic-methanol reagent permitted excellent mercaptan removal while using a recirculation rate of only 2 percent by volume of total solvent, based on the charge naphtha. For this reason the regeneration equipment is small and relatively inexpensive, and steam and utility consumptions are low. This high mercaptan-carrying power of the caustic-methanol reagent is further emphasized when it is realized that the extraction side of the plant was operating at the normal treating temperature of 100 deg. F.

A study of reagent loss is pertinent and illuminating, in that it throws into bold relief a feature of the caustic-methanol process which is outstanding. This feature is the separation of the two components of the reagent and returning them separately to the system. In addition to other flexibility features which will be mentioned later, charging the regenerated caustic soda solution to the top of the extractor tower causes this section to function as an efficient methanol recovery unit and, as a result, the outlet gasoline contains only 0.004 percent by weight of methanol. There is no other significant loss of methanol, which is important, since methanol loss is the only phase of the process which can run up the manufacturing costs to any tangible

Table 1

Semi-plant Extraction of Gray Treated Cracked Gasoline

Operating Conditions:	
Gasoline throughput	90 gal. per hour
Regenerated caustic	2.0 per cent by volume
Recovered methanol	0.8 per cent by volume
Treating temperature	100 deg. F
Charge inspection:	
Gravity, deg. API	58.1
ASTM distillation, in deg. F:	
Initial boiling point	98
10-per-cent point	146
50-per-cent point	248
90-per-cent point	372
End point	422
Reid vapor pressure, lb.	7

Comparison of quality:	Sour Gasoline	Treated Gasoline
Total sulfur, per cent by weight	0.110	0.067
Mercaptan sulfur, per cent by wt.	0.043	0.0005
Methanol, per cent by weight		0.004
Color (Saybolt)	24	25
ASTM Octane No:		
Clear	71.9	71.9
Plus 1 ml. TEL*	76.4	77.9
Plus 2 ml. TEL	78.7	80.2
Plus 3 ml. TEL	80.3	81.8
Induction period, hours:**		
Clear	8.25	4.50
Plus recovered phenol		8
Plus 0.0025 per cent by weight of U.O.P. No. 4 inhibitor		8.50

* Tetraethyl lead

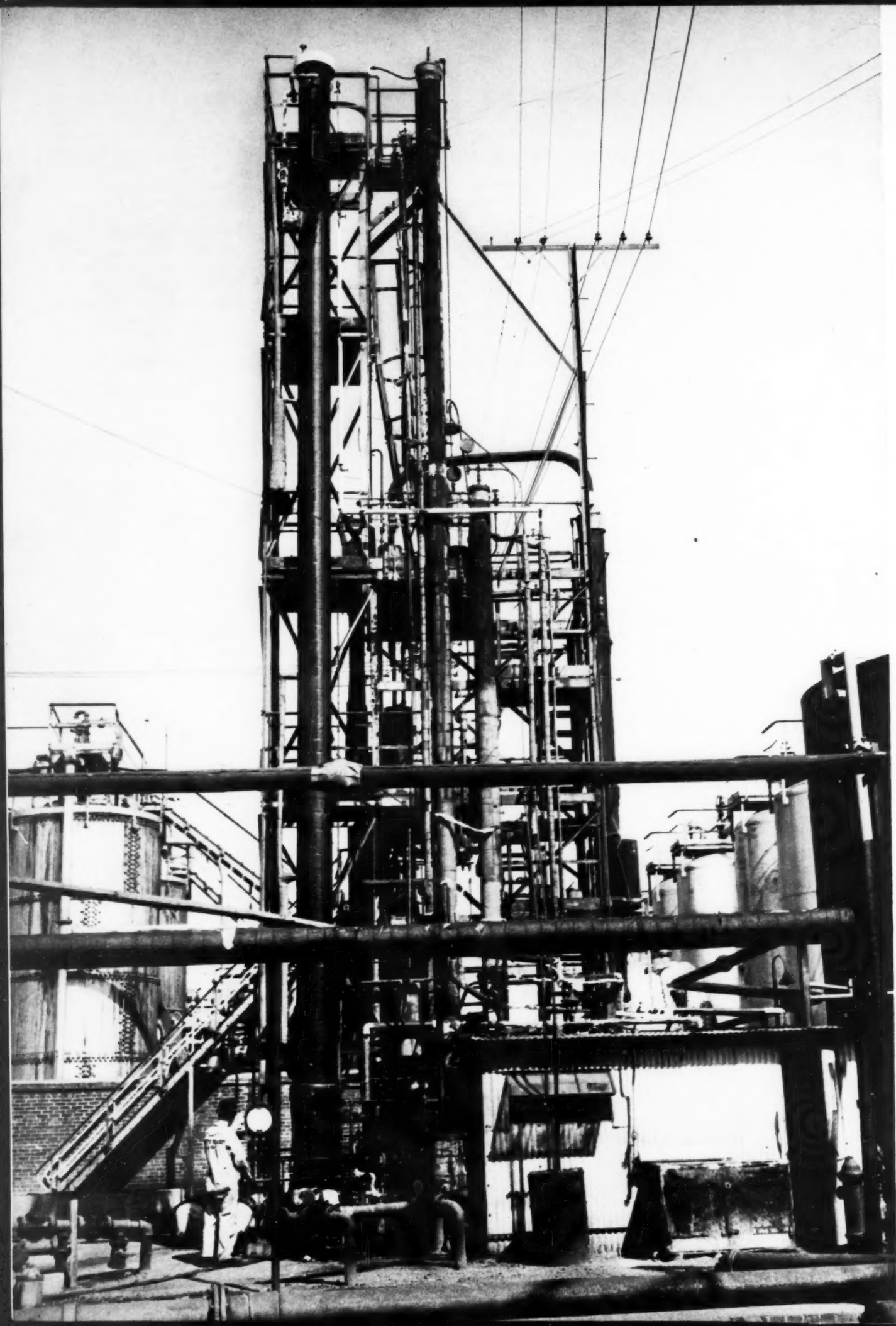
** ASTM tentative "gum stability of gasolines."

Table 2

Effect of Unisol Treating on Various Gasoline Stocks

Gasoline Stock	Boiling Range	Mercaptan Sulfur wt. % Before	Mercaptan Sulfur wt. % After	Total Sulfur wt. % Before	Total Sulfur wt. % After	% Mercaptan Removal	ASTM Octanes Before Treating 0	1	2	3	After Treating 0	1	2	3
Laboratory:														
Illinois Straight run	98–404	0.015	0.0002	0.038	0.023	98.7	51.6	60.5	65.5	68.5	51.8	61.5	67.0	70.9
Illinois Cracked	95–402	0.036	0.0002	0.09	0.06	99.4	67.1	73.0	...	76.5	67.1	73.8	...	77.8
East Texas Cracked Straight run blend	100–397	0.015	0.0004	0.035	0.020	97.3	70.4	78.0	83.3	85.3	70.8	79.0	84.5	86.5*
Michigan Cracked	.....	0.048	0.0003	0.13	0.10	99.4	66.5	72.0	...	75.8	66.5	73.6	...	78.3
†West Texas Straight run	90–357	0.028	0.0004	0.076	0.049	98.6	70.9	76.5	79.9	...	71.9	77.8	81.4	...
Panhandle Texas	.....	0.061	0.0002	0.15	0.10	99.7	63.2	68.3	...	72.2	63.2	69.2	...	73.4
West Texas Cracked	98–405	0.18	0.0002	0.77	0.50	98.9	66.0	68.8	...	71.4	66.5	70.6	...	74.2
Low Sulfur Cracked	98–410	0.035	0.0005	0.095	0.059	98.6	71.5	76.6	78.8	80.0	71.5	77.9	80.1	81.6
Semi-Plant:														
†West Texas Straight run	85–290	0.035	0.0004	0.076	0.041	98.9	69.2	75.4	79.4	...	70.6	77.2	80.9	...
West Texas Straight run	90–345	0.062	0.0007	0.119	0.056	98.9	68.5	75.2	78.0	...	72.0	77.5	81.3	...
†Low Sulfur Cracked	108–416	0.025	0.0003	0.096	0.072	98.8	69.2	74.7	77.2	78.5	69.4	75.5	78.5	79.8
							76.7	83.9	...	88.1	77.1	84.6	...	89.7*
Blend of Polymer and West Texas Cracked	96–390	0.0615	0.0007	0.190	0.128	98.9	74.0	78.0	80.5	81.5	74.0	80.0	82.2	83.8
							83.0	87.8	89.8	91.5	83.3	88.8	91.0	92.8*
High Sulfur Cracked	104–464	0.045	0.0005	0.248	0.182	98.9	68.6	72.8	74.9	76.0	68.8	73.6	75.9	76.9
Mixed Straight runs	120–360	0.008	0.0003	0.056	0.049	96.3	62.5	70.1	74.7	78.2	64.2	72.1	77.8	80.5
†South Texas Cracked	98–420	0.015	0.0003	0.071	0.056	98.0	70.0	73.8	76.4	77.9	70.0	74.5	77.7	79.1

† Mercaptans partially removed from the charge to these runs by caustic washing.
* 1939 CFRR (Research) Octanes.



degree. As a further advantage accruing to the separation of the solvents during regeneration, the control of contaminants in the recycled reagents is an important development. Acidic materials other than mercaptans, which tend to build up and foul the reagent are kept in hand by bleeding out small quantities of caustic soda solution from the bottom of the stripper tower. This gives contaminant control with low caustic consumption and no fouling of the methanol.

The extraction tower is a packed tower of conventional design; the various towers and drums on the regeneration side are equally unexciting from the design angle, when the fundamental data pertinent to the process are at hand to work with. The moderate temperatures and pressures avoid the necessity for use of alloy steels, except for the tubes and tube sheets of the reboiler on the caustic stripping tower. Here, the materials commonly used by the chemical industry for handling boiling caustic soda solutions are indicated. These materials are nickel, nickel clad steel, monel, special cast irons, etc. The plant is exceedingly simple in both design and construction, since condensers, heat exchangers, pumps and lines are all of conventional design.

Experience with a number of solvents teaches that any solution capable of extracting mercaptans will also extract, to some degree, any phenolic bodies present in the gasoline and, as a result, there sometimes will be a reduction in the oxidation stability characteristics of the gasoline. The Unisol process offers considerable flexibility in handling gasolines of varying phenol contents, since, in the regeneration step, the methanol and mercaptans are distilled from the caustic soda solution. The regenerated caustic solution contains phenols and other acidic components extracted from the gasoline, and, if the stability characteristics of the gasoline being treated are such that the final product is the better for removing substantially all of these phenols and using a synthetic inhibitor, the process can be controlled accordingly. If, on the other hand, the nature of the gasoline being treated permits the advantageous retention of the phenols, the process can be controlled to favor this retention.

The carrying power of the reagent for mercaptans is not impaired by this control, but the extraction of phenols from the gasoline is notably depressed. In all cases, the susceptibility of the caustic-methanol extracted gasolines to the action of synthetic oxidation inhibitors is excellent, and the major portion of the phenols which are extracted can be recovered. In this connection, it is of interest to note that, in the case of the gasoline treated and reported in Table No. 1, recovered phenols alone were able to restore the induction period to its original value.

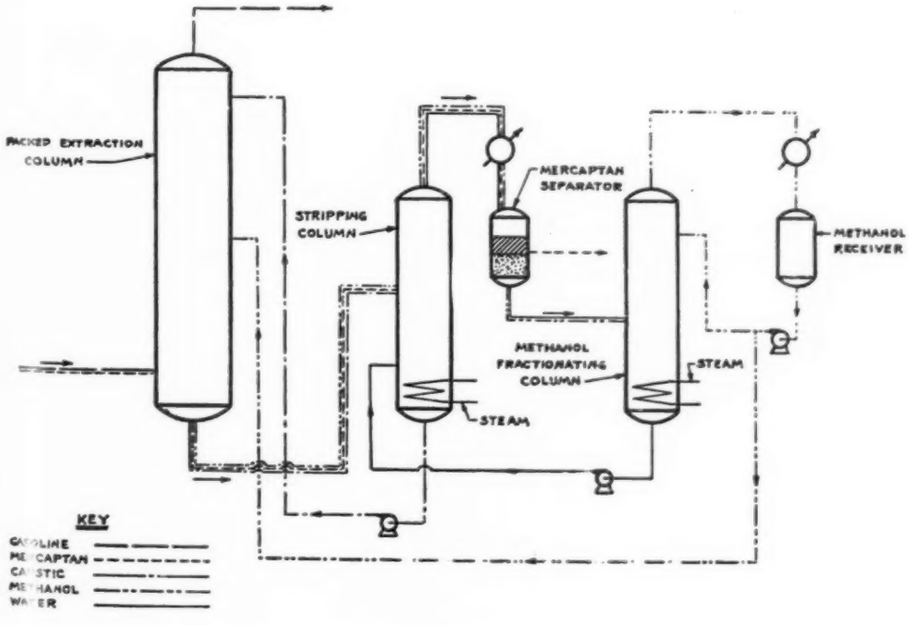
Table 2 tabulates the results of the semi-plant and laboratory treatment of a variety of gasoline stocks. In view of the excellent agreement between properly-controlled laboratory and semi-plant results on desulfurization and octane improvement, a laboratory evaluation of unknown stocks can be used for justification purposes. Clear octane numbers of the treated products were equal to or better than those of the sour stocks, which is noteworthy in view of the .25-1.0 number loss commonly encountered when converting, rather than extracting, the mercaptans. Further, the increased susceptibility to tetraethyl lead offers an attractive lead saving in all cases. The Unisol mercaptan extraction process offers the refiner an additional technique to use in his effort to meet the ever mounting octane requirement of present day competition. It has the following present day answers to the current problems of increasing octane level or decreasing tetraethyl lead usage: 1, Without loss of naphtha yield; 2, At low investment cost and with the minimum usage of strategic defense materials; 3, At low operating costs comparable with conventional doctor sweetening, and 4, Without dependence on crude source or process.

Acknowledgment

Acknowledgment gratefully is made to the technical personnel of the University Oil Products Company of Chicago, Ill., for assistance in the preparation of this discussion. This company is the licensing agent for the process under U. S. patents No. 1,968,842, 1,968,843, and 2,043,254, and pending applications.

Figure 3: The semi-commercial unit erected by Atlantic for further study of the possibility of almost complete removal of mercaptans from gasoline.

Figure 1 (right) compares mercaptan extraction by the use of caustic methanol and 47 percent caustic: Figure 2 (below) is a simplified flow diagram of the semi-commercial unit of the Unisol process.



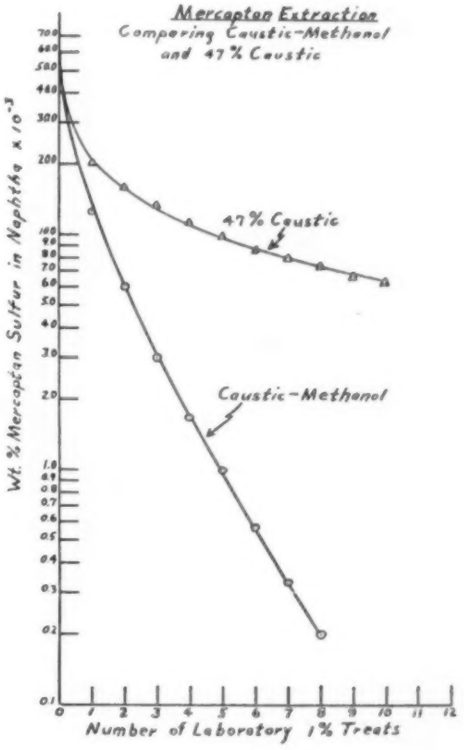
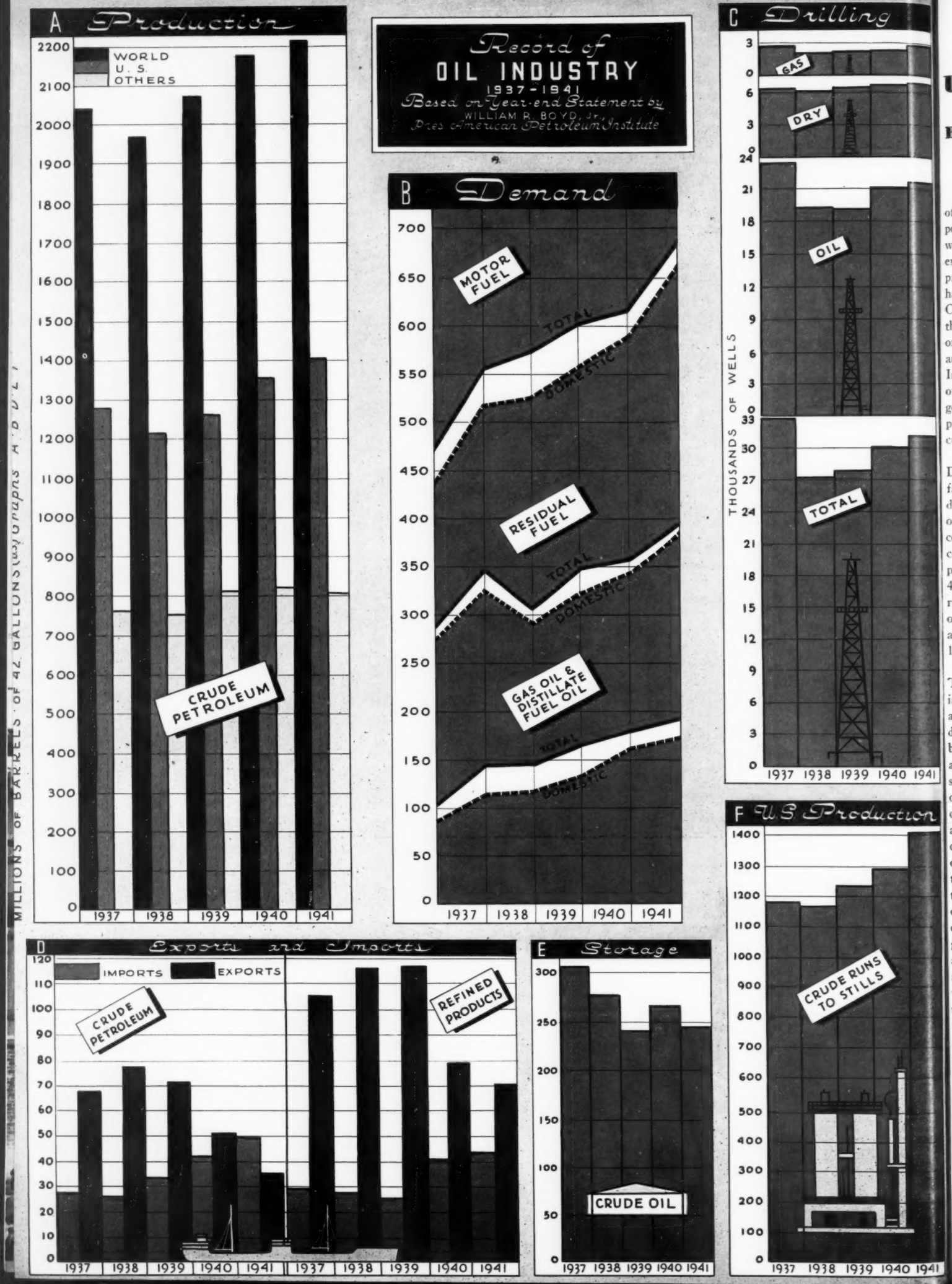


Fig. 1


Record of
OIL INDUSTRY
1937 - 1941
Based on Year-end Statement by
WILLIAM R. BOYD, Jr.
Pres. American Petroleum Institute
A Production
MILLIONS OF BARRELS OF 42 GALLONS EACH DAILY
WORLD
U. S.
OTHERS
CRUDE PETROLEUM
B Demand
MOTOR FUEL
TOTAL
DOMESTIC
RESIDUAL FUEL
TOTAL
DOMESTIC
GAS OIL & DISTILLATE FUEL OIL
TOTAL
DOMESTIC
C Drilling
THOUSANDS OF WELLS
GAS
DRY
OIL
TOTAL
D Exports and Imports
IMPORTS
EXPORTS
CRUDE PETROLEUM
REFINED PRODUCTS
E Storage
CRUDE OIL
F U.S. Production
CRUDE RUNS TO STILLS
1937 1938 1939 1940 1941

UNITED STATES PETROLEUM INDUSTRY IN 1941

By William R. Boyd, Jr.

President, American Petroleum Institute

THE DECLARATION of the existence of a state of war with the Axis powers found the American petroleum industry working at break-neck speed, with the thorough-going cooperation of the government, to meet new demands for petroleum products, and to eliminate bottlenecks before they have a chance to affect the supply of petroleum. On the very day Congress was acting to meet the treacherous attack of Japan, Petroleum Coordinator Harold L. Ickes, with keen foresight and patriotic resolve, was organizing a Petroleum Industry Council for National Defense—a sort of partnership arrangement between the federal government and the petroleum industry, to have petroleum play its all-important part in prosecuting the war that started on that day.

Demand for petroleum products in 1941 was by far the greatest in the 80-year history of the industry, amounting nearly to 1,600,000,000 bbl., or almost 10 percent above 1940. United States consumption alone increased more than 12 percent. At the end of the year the industry was producing crude petroleum at a rate of more than 4,100,000 bbl. a day, with predictions made that rapidly mounting needs would require production of 4,500,000 bbl. a day by the middle of 1942, and possibly of 5,000,000 bbl. a day by July 1, 1943 if not before that date.

The petroleum industry, by its very nature, is so integrated from oil well to consumer that almost any operating change in one small part of the industry has its inevitable reaction in other branches of the industry thousands of miles away. Defense demands already have made many such changes imperative, and more will come. In order that these changes might be made with complete fairness to all elements of the industry, and that the industry might make its maximum cooperative contribution to national defense without any hindrance because of possible illegality, the President on May 28 appointed Secretary of the Interior Harold L. Ickes as Petroleum Coordinator for National Defense. With the cooperation of the industry and of dozens of regional committees of oil men, he has prudently and effectively met the problems that so far have appeared, and is working closely in cooperation with the industry to assure completely adequate supplies of petroleum for all national defense needs in the future. On December 1, 1941 this government-industry cooperation was put on a more formal basis with the appointment of a national Petroleum Industry Council for National Defense, charged by the Coordinator with advising him and considering on its own motion matters relating to the coordination of the industry, and taking any action recommended by the Coordinator. The Council is composed of representative oil men from all branches of the industry and from all parts of the country.

During 1941 the industry was concerned with a number of potentially serious problems, among them the threat of a deficiency of petroleum supplies on the East Coast, huge additional demands for 100-octane super aviation motor fuel, reduced supplies of raw materials for the manufacture of tetraethyl lead, and the need for high priorities to assure the continuing normal operations of the industry. To meet these and other national defense emergencies, the petroleum industry spent hundreds of thousands of dollars in new capital expenditures during 1941, for new refining equipment, new pipe lines, and new tankships, along with the regular capital expansion of the industry. Shipyards turned out many new high-speed tankships in record time during the year, and many others are being built or are on order for oil companies and the Maritime Commission, with completion scheduled for 1942 and 1943.

Two national defense pipe lines—a 250-mile crude oil line from Portland, Maine to Montreal, Canada, and a 450-mile products line from Port St. Joe, Florida to Chattanooga, Tennessee—were completed before the end of the year, and a third products line, 1,260 miles long, from Baton Rouge, Louisiana to Greensboro, North Carolina, is nearing completion. Capacity of American refineries to produce 100-octane aviation motor fuel increased to nearly 44,000 bbl. daily (50,000 bbl. or 2,100,000 gallons with a greater proportion of tetraethyl lead) by the end of 1941, and plans sponsored by the Petroleum Coordinator call for quadrupling this huge capacity within the earliest possible time. The present capacity for this one grade of aviation fuel alone is far greater than the total capacity of the rest of the world combined, and is seven and one-half times the U. S. consumption of all grades of aviation fuel as recently as 1938.

All the agencies of the federal government having to do with petroleum and petroleum product production and transportation are busily engaged in working out cooperatively with the industry every problem as it arises. The Office of Petroleum Coordinator for National Defense is functioning with great intelligence and effectiveness. The state regulatory agencies and the Interstate Oil Compact Commission are geared into the program. And the petroleum industry and all its units are going to do a magnificent job.

The detailed 1941 figures covering the operations of the petroleum industry, estimated for the most part by the Institute, reveal that practically every figure is a new all-time high record. Crude oil production in the United States totaled 1,405,218,000 bbl., compared with 1,353,214,000 bbl. in 1940, but production in the rest of the world is believed to have declined slightly to 809,399,000 bbl. from 823,548,000 bbl. in 1940. The U. S. proportion of the world total therefore increased slightly to 63.5 percent. U. S. consumption of petroleum and products rose nearly 12 percent to an estimated 1,478,697,000 bbl., but exports dropped to 105,909,000 bbl. to make total demand 1,584,606,000 bbl. Stocks of crude petroleum were reduced about 20,000,000 bbl. during the year, ending at 244,000,000 bbl., but stocks of refined products on December 31, at 300,000,000 bbl. were virtually equal to the January 1, 1941 stocks. Drilling of wells increased slightly to 31,299, second busiest drilling year in the industry's history. Of the 1941 wells, 21,584 were completed successfully as oil wells and 2,869 as gas wells. The remaining 6,846 were unsuccessful dry holes. The country's refineries processed a record of 1,406,976,000 bbl. of crude petroleum in 1941, and met new peak demands for all major products except kerosene. Total domestic and export demand for these products, with high domestic demands more than making up the further decreases in exports, were: Motor fuel, 683,843,000 bbl.; distillate fuel oil, 188,513,000 bbl.; residual fuel oil, 395,527,000 bbl.; kerosene, 71,400,000 bbl. and lubricating oil, 41,500,000 bbl. The most spectacular increase was reported in the domestic demand for lubricating oil, which gained nearly 30 percent over 1940. Exports of lubricating oil also declined less than the exports of any other major product such as gasoline and fuel oil.

Wholesale prices of petroleum products, according to the Bureau of Labor Statistics, remained far below the average for all commodities, but rose from an average index of 50.0 in 1940 to 57.2 for the first 10 months of 1941. This compares with an average of 87.1 for all commodities. Crude oil prices, as indexed by the 36-degree Oklahoma-Kansas quotation, increased from $1.02 in 1940 to $1.17 at the end of 1941. The average retail price of gasoline in 40 representative U. S. cities, exclusive of taxes, gained slightly in 1941, rising from 12.75 cents in 1940 to 13.30 cents a gallon. The all-time low was 12.41 cents in 1933. Gasoline taxes increased again in 1941 for the third successive year to the all-time high average of 5.93 cents a gallon, equivalent to a sales tax of 45 percent; the 1940 average was 5.66 cents. Average cost to motorists was therefore 19.23 cents, against 18.41 cents in 1940. Total gasoline taxes reached the staggering total of $1,335,000,000, of which about $965,000,000 were collected by the states, up nearly 12 percent from 1940, and about $370,000,000 by the Federal Government, an increase of 31 percent compared with the previous year.

Approximately 34,635,000 motor vehicles were in use during 1941, with about 31,600,000 being operated at the end of the year. On the average these vehicles used 800 gallons of motor fuel in 1941, compared with 752 gallons in 1940.

George A. Holton who has been appointed general manager of Sylvestre Oil Company to succeed Mr. Breen in directing the distribution of fuel oil in New York City, Westchester and Fairfield counties. Mr. Holton was formerly assistant manager of the company under Mr. Breen.

C. A. Breen, vicepresident and general manager of the Sylvestre Oil Company since 1937, has recently been appointed assistant manager of the New York state division of Colonial Beacon Oil Company. Mr. Breen's offices will be in New York City and he will continue as vicepresident of Sylvestre, which is a Colonial Esso marketer of industrial and domestic fuel oils.

Thomas Midgley, Jr., vicepresident of the Ethyl Gasoline Corporation, who has been awarded the 1942 Willard Gibbs Medal of the Chicago Section of the American Chemical Society, one of the highest distinctions in chemical science. Dr. Midgley was cited for his discovery of tetraethyl lead, which made possible spectacular advances in automotive and aircraft engines.

Earl Rives, who resigned from the Reed Roller Bit Company on January 1st, to become associated with the Wallace Davis and Company advertising agency in Houston, Texas. Mr. Rives has been connected with the advertising department of the Reed Company for the past four years and has experience in commercial photography and a wide acquaintance in the industry.

Bert M. Brock, who has recently been appointed manager of industrial relations for John A. Roeblings Sons Company. Mr. Brock was formerly connected with the U. S. Steel Company and the Carnegie Illinois Steel Corporation.

FOREIGN OIL LEGION

A. W. Herrington, president of the Marmon-Herrington Company, has recently been elected national president of the Society of Automotive Engineers. Mr. Herrington, whose company is engaged in the manufacture of highly specialized automotive equipment for civilian and now almost exclusively military services, is also chairman of the board of directors of the Merz Engineering Company, subsidiary of Marmon-Herrington, manufacturing precision gauges, instruments and machines.

Mr. Herrington is well known for his outstanding accomplishments in the automotive field. Of particular importance at this time is his intimate knowledge of military transport problems, the basis of which he acquired during the first World War and which he has since enlarged by extensive travels in remote parts of the world where Marmon-Herrington equipment was being subjected to difficult and unusual tests.

The company's equipment is well known in the oil industry and an outstanding example will be remembered as the service performed by these trucks under the particularly difficult conditions encountered in the construction of the great Iraq pipe line. Mr. Herrington has declared his intention of helping through the S.A.E. to synchronize the efforts of the automotive industry in behalf of the American war efforts.

At a meeting of the New York Chapter of Nomads on January 9, 1942 new officers were elected for the coming year; they are pictured at right, from left to right standing: J. H. Baird and J. A. Thomas, Board of Regents; A. V. Simonson, Sgt.-at-Arms; G. B. Flanigan, Deputy Sgt.-at-Arms; C. J. Delay, assistant secretary; Seated, F. J. Olson, treasurer; Val R. Wittich, secretary; Russel D. Heath, president; and I. Frank Brown, vicepresident.

At the dinner at Sherry's following election of officers for the N. Y. Chapter of Nomads: F. J. Olson, Russ Heath, Doc Simms, guest speaker, Jim Thomas, H. B. Cheswick and Fred Convers.

Other guests at the January 9th. meeting of the N. Y. Chapter of Nomads photographed just before dinner: Left to right; George Flanigan, Art Simonson, Howard Slater and R. M. Dinges.

The retiring 1941 officers of the N. Y. Chapter of Nomads assembled at the January 9 meeting. Standing, left to right; F. T. Ostrander, John H. Baird, and F. J. Olson; Seated, left to right; Fred Convers, Russ Heath, Jim Thomas and H. B. Cheswick.

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing with Technical and Economic Aspects of the Petroleum Industry — Edited by Dr. O. W. Willcox.

GEOPHYSICS:

Factors Influencing the Electrical Resistivity of Drilling Mud—John E. Sherborne and Wm. H. Newton, before AMERICAN INSTITUTE MINING METALLURGICAL ENGINEERS, PETROLEUM DIVISION, Los Angeles Meeting, October, 1941.

During recent years, the practice of "electrically logging" a geologic formation by means of a system of electrodes lowered in a well-bore, has provided data of inestimable value as to the nature of the sediments penetrated. Thus, it is generally possible to distinguish readily between shales, sandstones, cherts, limestones, and other rock forms. The distinguishing characteristics recorded in this manner have made possible long range and closely detailed mapping and visualization of deeply buried structures to a degree not to be obtained with a reasonable expenditure of money by any other means at present in use.

Because the drilling fluid must be the medium through which the electric logging device is made to traverse the formations penetrated by a borehole, and since, in general, the drilling mud completely surrounds the electrodes, a knowledge of the electrical properties of this fluid is essential to the thorough analysis of electric logs. There have long been considerable field data to indicate the great influence the nature of the drilling fluid has upon electric logs, but, to the knowledge of the writers, no quantitative information has been published.

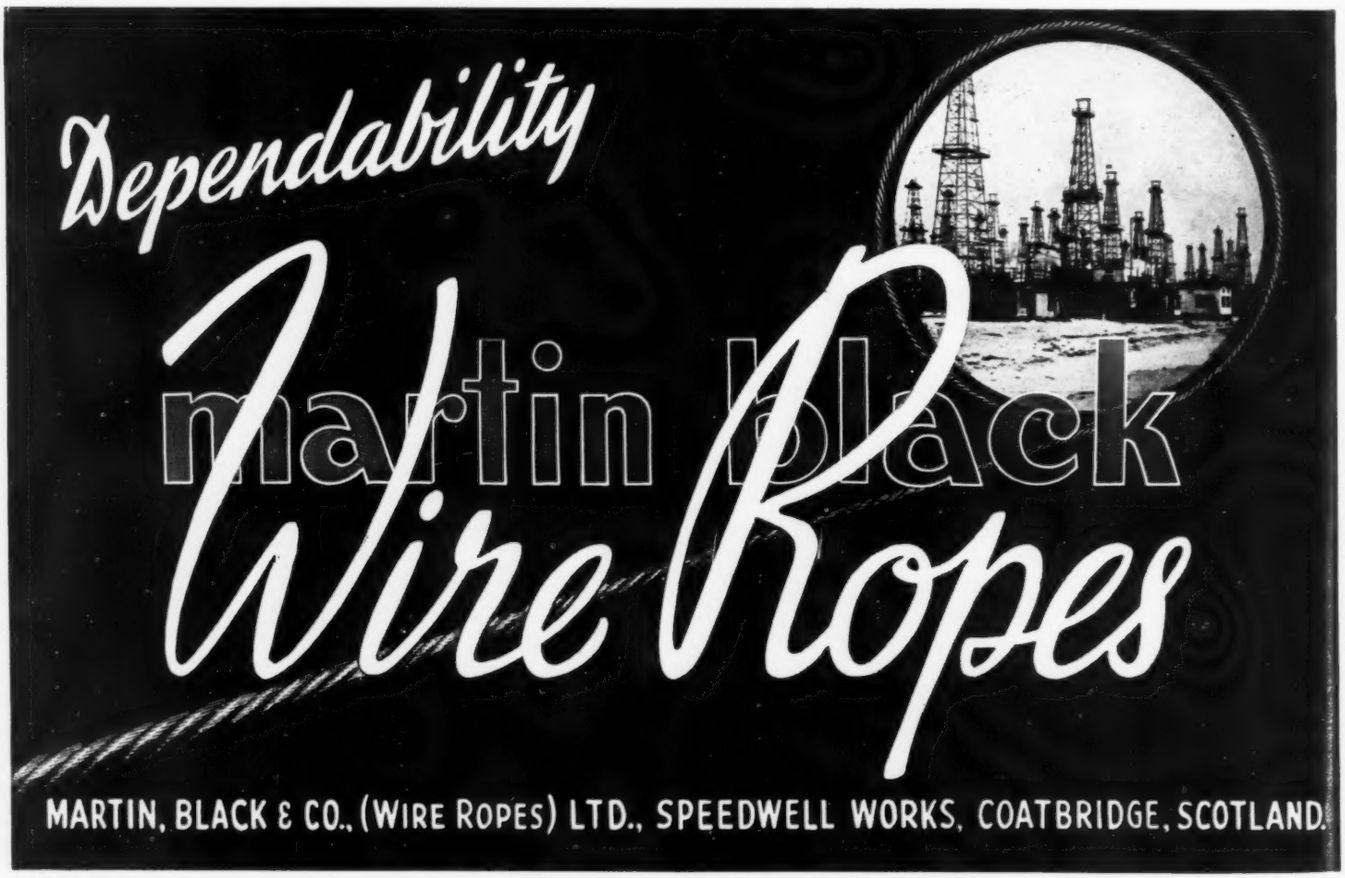
The authors therefore investigated the subject, using five types of mud commonly used in California. They have amply demonstrated that the effect of mud on electric logs is profoundly affected by various treatments given to the drilling fluid. Hence the interpretation of an electric log should take into consideration the resistivity of the drilling mud and its filtrate.

Perhaps the most important point is that temperature has a great influence on the resistivity of the drilling fluid, and that electric logs of different wells or of the same well at different times will not be strictly comparable unless the temperature and the specific resistivity of the drilling mud are also recorded.

GEOLOGY

Marine Sedimentation and Oil Accumulation on Gulf Coast. I. Progressive Marine Overlap—Doris S. Walkin and Dorothy A. Jung, in BULLETIN AMERICAN ASSOCIATION PETROLEUM GEOLOGISTS, Vol. 25 (1941), No. 11, pp. 2010-2020.

The authors point out that a large part of the Gulf Coast petroleum reserves are in transgressive sands. In fact, an authority is quoted as saying that more than 90 per cent of the oil produced on the Gulf Coast comes from sands at the base of



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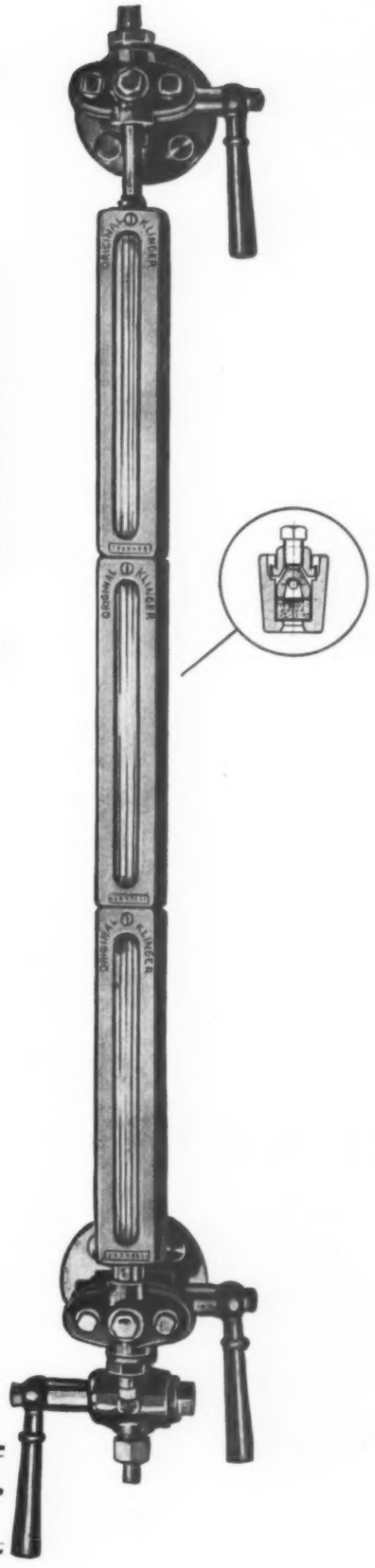

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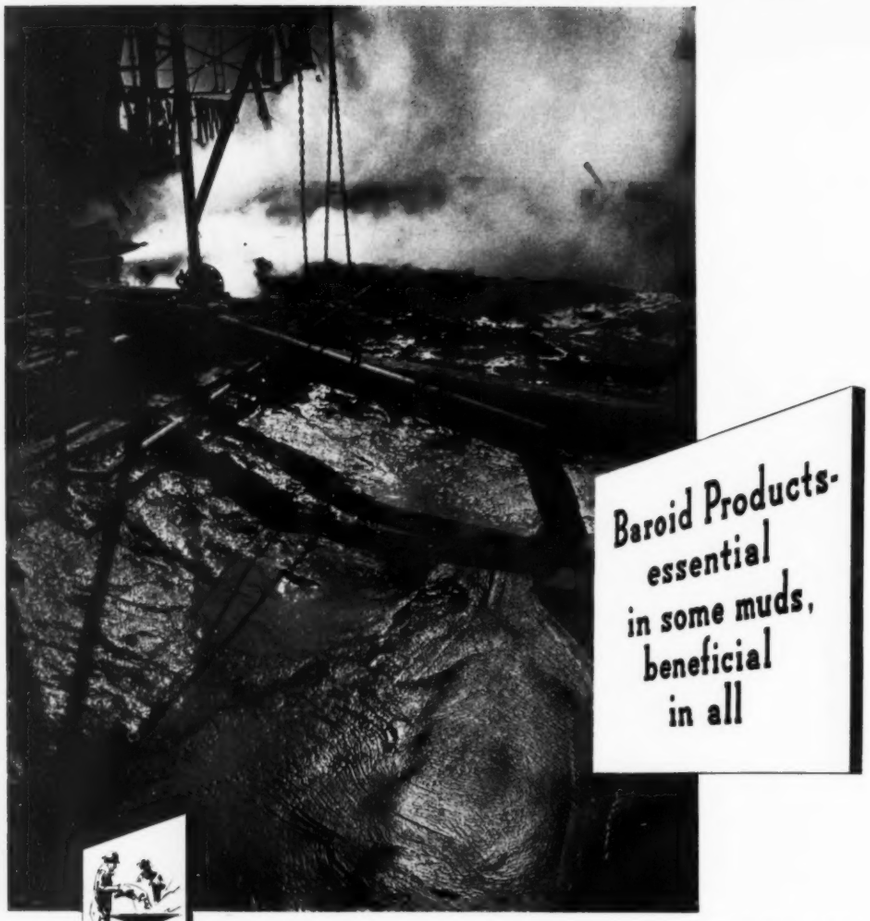

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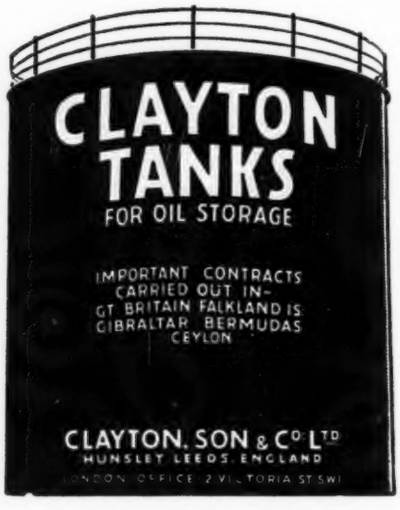

marine transgressions, for example the upper Wilcox, the "Cockfield," Marginulina-Frio, and lower Miocene producing sands.

The reason for calling attention to this circumstance is that, since many if not most structural traps have been located, the petroleum geologists have begun to investigate the possibilities of stratigraphic traps.

Marine transgressions are a principal agent in the formation of stratigraphic traps. By a marine transgression is meant the inland movement or advance of the sea which results in a sequence of sediments called a progressive marine overlap. In the course of time this causes the older formations to be overlapped by younger formations shoreward. As the sea moves landward, deposition takes place farther and farther inland from the original shore. It is this overlapping of formations of different natures that produces stratigraphic traps, where sand reservoirs may be sealed by an overlying shale or other impermeable cover. This process has been a prominent feature in the history of the whole Gulf area.

Since the marine overlap presents conditions well suited for a petroleum reservoir, the writers believe it is advantageous to make local and regional studies of possible producing zones with a view to deciding whether they are transgressive in origin. When this is done, it may be possible to determine the updip and downdip limits of marine sandy zones from which oil may be produced.

DRILLING

Causes and Prevention of Drill-Pipe and Tool-Joint Troubles—R. S. Grant and H. G. Texter, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual meeting, San Francisco, November, 1941.

The authors describe drill-pipe and tool-joint troubles and means of preventing them.

It is stated that true twistoffs, spiral tears, and tension failures have been practically eliminated by improved pipe manufacturing and drilling practices. Failures at the last-engaged thread and leakage through threads also have been practically eliminated through improvements in design and in installation methods.

Fatigue breaks are the most common type of drill-pipe trouble today. They may be pure fatigue failures, but much more often are accelerated by notches or scars and by corrosion. Fatigue breaks may be reduced greatly by the use of adequate drill-collar weight, and this is probably the most important recommendation that can be made to increase the life of drill pipe.

Troubles arising from worn pipe best can be prevented by keeping the pipe straight. Pipe usually is made crooked by running the string in compression. Collapsed pipe, although rare, usually occurs while making drill-stem tests.

Wall eccentricity, internal erosion, and magnetism, although often discussed, have never been proved to be causes of drill-pipe failures.

Longitudinal splitting of the pipe ends of tool joints has been practically eliminated by the use of upset forgings. Splitting or swelling of the pin and box ends can be prevented by the use of special lubricants.

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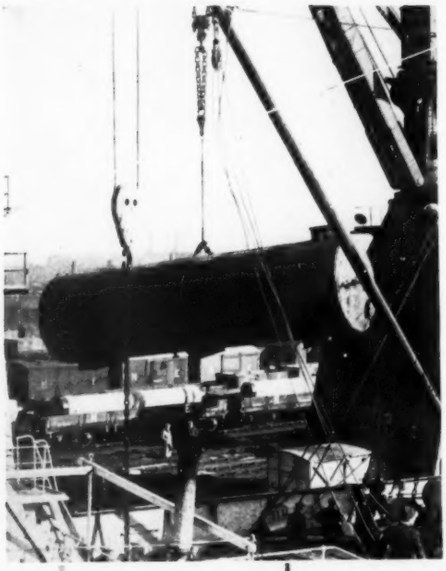

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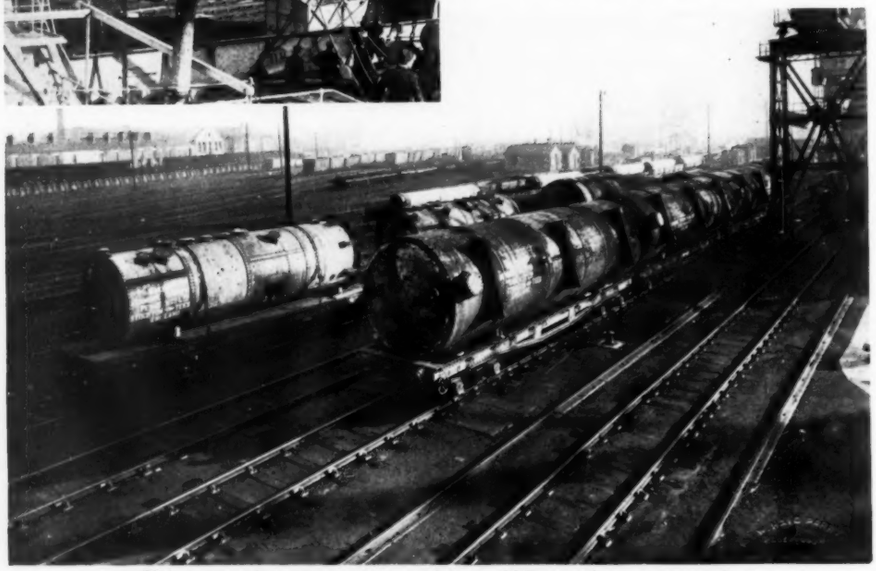

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Galling and wobble failures are the two most common tool-joint troubles today. The former best can be prevented by careful breaking in and adequate lubrication.

Wobble failures result from operation of the joint while loose, and are aggravated by the modern practice of running drill strings in tension. They best can be prevented by adequate tonging and by care in handling to prevent damage to shoulders.

Tool-joint wear cannot be prevented, but the effects and costs entailed can be minimized by the use of easily replaceable tool joints, oversize tool joints or wear subs, and by resleeving or hard-surfacing of either the tool joints or subs.

OPERATION

Oil-Well Tests Suggest New Rating Standards—H. E. Dralle and E. H. Lamberger, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

In oil-well pumping there are many known variables which directly affect the design and application of equipment used in the economical production of oil. To ascertain the individual effects of these variables on the performance and ratings of oil-well equipment and to augment the many theoretical considerations already given to them, Phillips Petroleum Company, Sargent Engineering Corporation, and Westinghouse Electric and Manufacturing Company jointly made a series of more than 200 tests, extending over a continuous period of 6 months.

The actual tests included independent variation of the speed, stroke length, counterweighting working-barrel size, tubing diameter, and type of prime mover. Under these varying conditions, oscillographic film was used to show 14 simultaneous records of instantaneous loads and displacements occurring during a pumping cycle.

Instruments were placed in the incoming power line, in the low-speed gear shaft, on the pitman, at two different points on the walking beam, on the polished rod, and at two different points in the sucker-rod string. Correlated with these were polished-rod dynagraph charts and bottom-hole dynamometer records.

The paper covers that part of these tests which suggests the development of new formulas for predetermining, from a known set of well conditions:

1. Peak polished-rod load.
2. Pump plunger-stroke.
3. Peak crankshaft torque.

These new formulas, with supporting data, are given, and results from their use compared with those obtained from existing formulas and with actual test results. Suggestions also are made that other perplexing problems incident to oil-well pumping may be solved conveniently with these same basic and fundamental test data.

Concerning the significance of their work the authors have to say:

Neither time for analysis nor space for presentation permits disclosure in this paper of all data that are of vital interest to the production branch of the industry; but there are in these existing test records, besides the data for developing a new formula already completed and presented in this paper, posi-

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tive answers to many other perplexing problems incident to beam pumping of oil wells, from the pump to the prime mover. For example, there is evidence that there can be developed a method for determining more accurately prime-mover horsepower from the hydraulic horsepower, and that there can be determined the true relation between loads at the polished end and at any point in the string.

REFINING

Precise Commercial Fractionation in 1,000 Bbl. Stedman Unit—L. B. Bragg and F. Morton, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

The paper describes the design and operation of a commercial fractionation unit (1,000 bbl. per day) utilizing Stedman packing. The tower is packed with Stedman packing [6-in. triangular sections; *cf.* Bragg, *Trans. Am. Inst. Chem. Eng.* 37, 19-50 (1941)] having a cross-sectional area of 78.5 sq. ft. and a packed height of 7 ft. Three different types of operation are described:

A. Fractionation of a straight-run gasoline into seven narrow-boiling fractions, a composite slop fraction, and a still residue. Two of these fractions which contain, respectively, substantially pure *n*hexane and *n*heptane and the residue may be isomerized, cyclized, or reformed. The other fractions, containing substantially all the *iso*paraffins, naphthenes, and aromatics, and the *n*pentane may be variously reblended to give high-octane-rating complementary spirits suitable for blending with *iso*octane or alkylates to give 100+ aviation fuels.

B. Fractionation of special fractions—the example given being the production of a concentrate of isomeric hexanes from a low-octane-rating gasoline, the fraction so obtained having a leaded octane rating of greater than 100.

C. Fractionation of a narrow-boiling sidestream from conventional topping unit (boiling range, 210 to 250 deg. F.) to give substantially pure toluene. Brief mention is made of the efficiency, holdup, friction loss, etc., of the packing. The boiling ranges and properties of tank samples are included.

The paper is presented under the joint sponsorship of the Foster Wheeler Corporation, New York, N. Y., and Trinidad Leaseholds, Ltd., Pointe-a-Pierre, Trinidad, B.W.I., the unit having been erected and tested at the latter's refinery in Trinidad.

The authors conclude that the batch Stedman unit offers the possibility of making a large number of cuts from a single charging stock, with good control and exact fractionation, even with varying feed composition. The present state of the art of controlling continuous bubble-tray batteries does not permit satisfactory operation to meet such requirements. In addition, batch operation permits one to take advantage of the possibility of using reduced reflux ratios in the early stages of the run, thereby reducing utility consumption and the size of the tower, condenser, and heating coils. Batch operation permits wide flexibility in the operation of the unit such as may be required to meet changing market demands.

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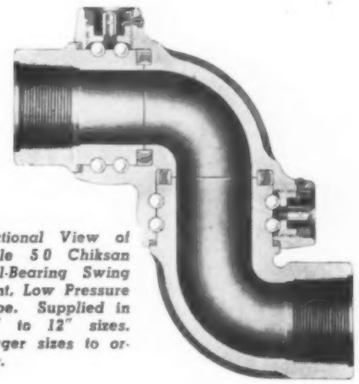

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ASPHALT & TAR

Colloidal Stability of Asphalts—Hans F. Winterkorn and George W. Eckert, in INDUSTRIAL ENGINEERING CHEMISTRY, Vol. 33 (1941), No. 10, pp. 1285-1289.

Prediction of the service behavior of asphaltic materials by means of simple laboratory tests is important to both the asphalt producer and the road builder. The conventional physical specification tests, which were valuable as quality indicators as long as only a few well-defined asphalts were on the market, are failing in this role in view of the increasingly varied products which are now sold under the collective name of "asphaltic bitumen."

It has been found that failure of bitumen to function properly in a pavement is usually associated with excessive hardening. As long as this hardening is caused only by loss of volatiles, it can easily be remedied. On the other hand, this hardening may be due to a change in the colloid structure of the bitumen.

It now appears that the Oliensis spot test should be recognized as essentially a method for determining the inherent colloidal stability of a bitumen, and it should receive closer attention from manufacturers of these products. The authors point out that it will be well to use a wider range of solvents for asphalts of different sources, and give a number of suggestive hints.

BOOK

A.S.T.M. Standards on Petroleum Products and Lubricants—Prepared by A.S.T.M. committee D-2. Published 1941 by AMERICAN SOCIETY FOR TESTING MATERIALS, Philadelphia, 398 pages; $2.00.

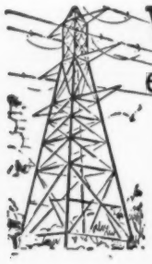
The 16th edition of this publication issued annually by the American Society for Testing Materials since 1926 provides in compact form all of the test methods, specifications, definitions and charts developed through the work of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants. The 1941 book includes 69 methods of testing, 11 specifications, and 2 lists of definitions of terms. In addition, four proposed new methods, approved for publication as information and for comment, are given covering tests for neutralization number (by electrometric titration, and for crankcase oils), potential gum in aviation gasoline, and conversion of kinematic to Saybolt Furol viscosity. A revised Diesel fuel oil classification is also included.

Important new standards in the volume provide specifications for aviation gasoline and tests for knock characteristics of aviation fuels, standardized method of determining the ignition quality of Diesel fuels, and procedures for testing the aniline point of petroleum products and for carbonizable substances in paraffin wax. During the year some 13 standards were revised; full details are given in the annual report of Committee D-2 published in the compilation.

CHEMISTRY

Progress Report on the Hydrocarbons in the Kerosene Fraction of Petroleum—Frederick D. Rossini and Beveridge J. Mair, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

The authors report progress on API Research Project 6. Eight individual hydrocarbons have been isolated from the kerosene fraction, and while the work is still incomplete, the authors feel warranted in stating the interesting conclusion that the analysis of the kerosene and other fractions below the lubricant fraction, because they are less complex, will yield more information with less effort about the composition of the lubricant fraction than a direct attack on the lubricant fraction itself. Already valuable information along these lines has been obtained. Thus the presence in the kerosene fraction of tetrahydronaphthalene and its homo-



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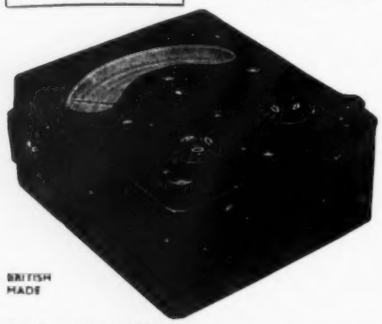

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logs is consistent with the previous finding that the lubricant fraction contains compounds in which both aromatic and naphthene rings occur in the same molecule. Similarly, it has been shown previously that in the lubricant fraction those molecules containing two aromatic rings were in large part ones in which these aromatic rings were linked together through two carbon atoms, as in naphthalene and its homologs. As previously reported, these latter compounds have been isolated already from the kerosene fraction.

GENERAL

Sulfur Limits in Gasoline—C. D. Lowry and Gustav Egloff before NORTH AMERICAN GASOLINE TAX CONFERENCE, Houston, August, 1941.

The theme of this paper is that legal specifications putting a limit on the sulfur content of gasolines are obsolete and should be dropped. First, because all modern cars are now equipped for thermostatic control of radiator temperature and have provisions for crank case ventilation; and secondly, putting the limit on sulfur at 0.1 or 0.2 per cent makes refining operations more expensive, and besides tending to needlessly increase the cost of motor fuel, tends to exclude the use of certain classes of crude oils.

Sulfur in the elemental form and mercaptans are of course objectionable and should be removed. The practice of putting a limit on sulfur in gasoline started back in the days when all gasoline was straight-run and derived from Pennsylvania sources, where no gasoline had more than 0.1 per cent of S, so it seemed natural to take that figure as the limit. When gasoline production was extended to cracked Mid-continent and West Texas, such a limit was productive of much inconvenience.

Since then most specification writers have seen the light. In 1941 there were fourteen states whose laws specifically allowed sulfur higher than 0.1% as follows:

	Per Cent Sulfur Permitted	
Idaho	0.25	
Minnesota	0.25	
New Mexico	0.25	
North Dakota	0.25	
Utah	0.25	
Iowa	0.20	(Benzol blends)
Montana	0.20	
Oklahoma	0.20	
Texas	0.20	
Wyoming	0.20	
Mississippi	0.15	
North Carolina	0.15	
Alabama	0.12	
Colorado	0.12	

Besides this, at last report twenty-two states and the District of Columbia had no specifications, six required 0.10% sulfur, and six others provided that gasoline sold in that state should follow the Federal specification. This may be a somewhat difficult thing to do, as the Federal authorities, apparently beginning to take a realistic view of the situation, have become considerably more lenient and accept gasoline in Texas, for example, up to 0.25% sulfur, and in Oklahoma to 0.20%, while in other states holding rigidly to 0.10%. The inconsistency of this is apparent, as it is scarcely credible that sulfur would respect state boundaries, so that above 0.1% would be harmful in one state and do no damage in an adjacent jurisdiction.

Characteristics of California Crude Oils—R. C. Mithoff, G. R. MacPherson and F. Sifos, before AMERICAN PETROLEUM INSTITUTE, 22nd Annual Meeting, San Francisco, November, 1941.

The naphthenic character of California crude oils is reflected in the high octane number of the straight-run gasolines. The gasolines with an end point of 390 deg. F., after they have been blended with natural gasoline to obtain 170 deg. F. at the 20-per-cent point, usually range in octane number from 60 to 73 CFR motor method. A large proportion of them is in the upper part of this range. Corresponding gasolines from the Mid Continent, are usually of about 50 to 60 octane number.

Brief description is given of the crude-oil-analysis methods employed by the Standard Oil Company of California. Based upon results of these analytical methods, California crude oils are compared with oils produced elsewhere.

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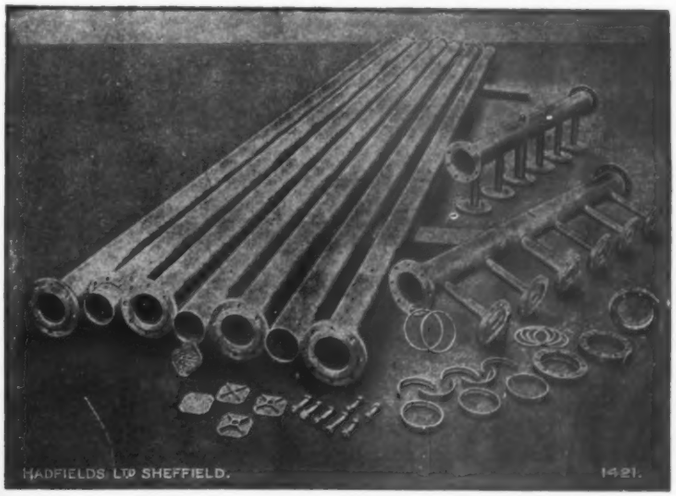

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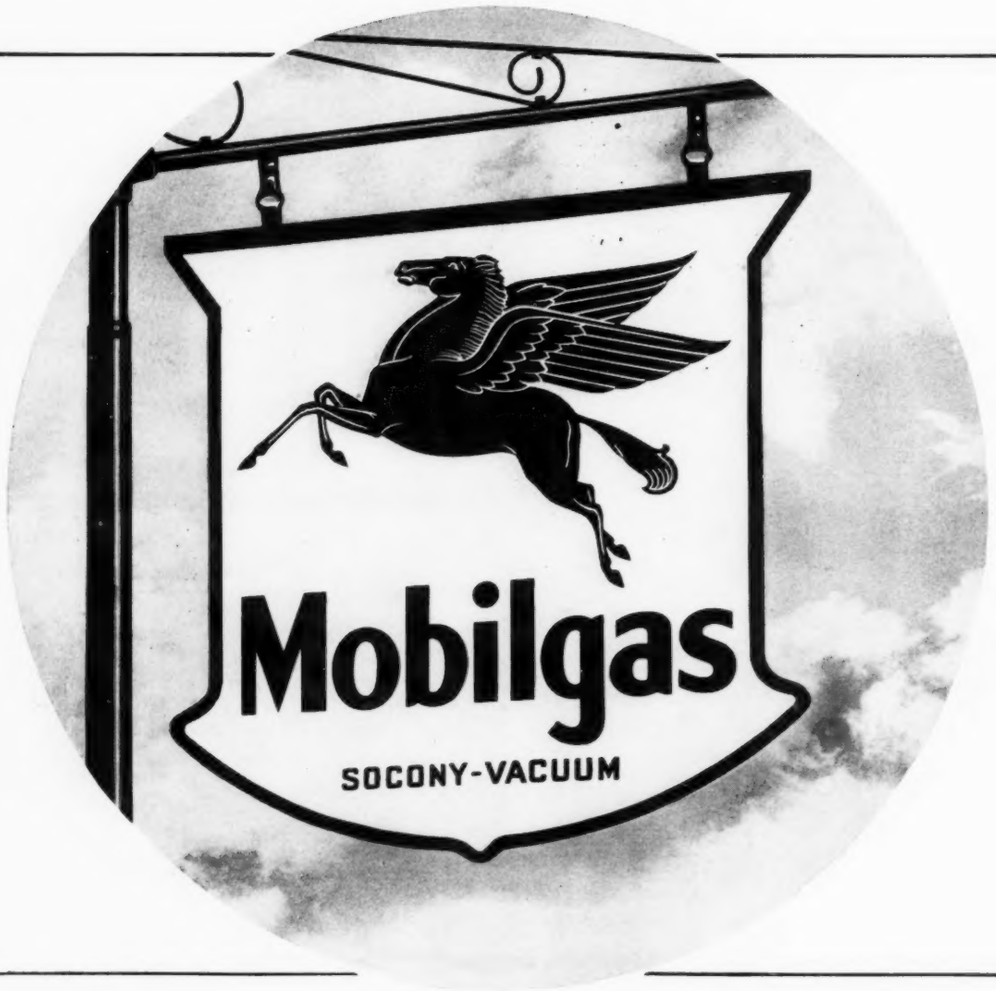

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